STABILITY, QUALITY AND NUTRITIONAL ATTRIBUTES OF FRANKFURTERS WITH LOW FAT AND ADDED POLYUNSATURATED FAT

BY

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TO MY MOTHER ALICIA
WITH LOVE AND GRATITUDE

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STABILITY, QUALITY AND NUTRITIONAL ATTRIBUTES OF FRANKFURTERS WITH LOW FAT AND ADDED POLYUNSATURATED FAT

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Six different treatments (11.36 kg batches in triplicate) with different final fat content (12, 20 and 29%), with and without peanut oil substituted for beef fat (0%, 60%), were prepared to evaluate the effect of fat level and polyunsaturated fat content on emulsion stability, yield, cholesterol content, fatty acid profile, shelflife, juiciness, flavor intensity, sensory and instrumental color and textural characteristics, and overall acceptability of frankfurters. Final products were analyzed fresh and after 6 weeks storage at $4^{o}C$. The effect of cooking and storage condition on the fatty acid profile was also evaluated. Finally, a study of the potential hyperlipidemic effect of products with 12 and 29% final fat content with and without peanut oil was conducted using rabbits as experimental units.

Emulsion stability, yield, and juiciness scores were reduced ($p<0.05$) when the final fat content was reduced to 12%. The fatty acid profile was affected by the addition of peanut oil, but not by fat

level treatments. The polyunsaturated to saturated fatty acid ratio increased from 0.11 to 0.68 when peanut oil was added. No differences were observed in fatty acid profile due to either cooking or storage conditions. Cholesterol content increased when final fat content increased and/or oil content decreased. However, an interaction was observed among the fat content and oil levels for cholesterol content, indicating that the linear increase in cholesterol content due to the increasing total fat was dependent on the level of oil used.

Firmness and darkness of the product increased as the final fat content decreased. Flavor intensity was highest at 12% final fat content. No rancid flavor development was detected during the six weeks of storage at $4^{o}C$. Flavor, color and texture of the product remained stable during the six weeks storage condition. All the different treatments were evaluated as acceptable by consumer panelists. However, those treatments with 12% final fat content received significantly ($p<0.05$) lower scores.

All the different treatment combinations significantly ($p<0.05$) increased the serum triglyceride levels of rabbits when compared to a control diet. Those treatments with higher fat content produced a greater increase. Inclusion of peanut oil in the diets of rabbits produced a lower serum cholesterol response when compared with the dietary treatments without peanut oil.

INTRODUCTION

The nutritional quality of the food supply has emerged as a topic of increasing concern to consumers, producers, and government agencies. Interest in the proposed relationship between dietary fat and development of coronary heart disease exemplifies this concern. Eventhough there is not conclusive evidence to support that relationship, the American Heart Association has recommended to the American public to reduce the consumption of cholesterol and saturated fatty acids, and, at the same time, to increase the consumption of polyunsaturated fatty acids.

Because of their content of cholesterol and saturated fatty acids, animal products have been involved in a controversy concerning their role in the atherogenic process. Meats of all kinds contain cholesterol. It is present in the lean muscle and in the adipose or fatty tissue. However, higher values of cholesterol have been found for separable fat than for separable lean tissue (Rhee et al., 1982).

Saturated and monounsaturated fatty acids are predominant in meat fats. As a means to increase polyunsaturated fatty acids in meat, ruminant animals have been fed with diets containing polyunsaturated oil (Ford et al., 1975). Although meats with elevated levels of linoleic acid have been produced, their disadvantages include increased cost of beef production and flavor problems (Blankenhorn, 1985).

While meat is relatively low in cholesterol and total fat content, meat products such as patties, bologna, franks, etc., range in fat content between 20 and 30%. Current consumer interest in reduced calorie food has led the American Meat Institute to petition USDA for a light standard of identity for cooked sausage. The standard would specify a maximum of 22.5% fat and a minimum of 11.5% protein (Anonymous, 1985).

Fat is added to meat products for economic, flavor and texture reasons. The reformulation of frankfurters to produce a low fat product must include the problem of toughness. Different approaches have been used to minimize this problem, including utilization of water-gum suspension (Foegeding and Ramsey, 1986) and soy protein (Sofos and Allen, 1977) to increase water content; however, no success has been obtained.

Since the challenge in marketing a reformulated food product is to demonstrate a real or perceived advantage in terms not only of its sensory quality and convenience but also of its nutrient delivery, one alternative could be the addition of vegetable oil, which in addition to providing higher polyunsaturated fatty acids and lower cholesterol content to the final product may aid in improving tenderness of low fat frankfurters. However, the inclusion of vegetable oil may cause emulsion destabilization because oils have lower melting points than animal fats.

This study was conducted to evaluate the effect of reducing the final fat content and the addition of peanut oil on the stability, shelflife, quality properties, overall acceptability, fatty acids

profile and cholesterol content of frankfurters, and to evaluate the hyperlipidemic effect of these different treatments using rabbits as experimental units.

REVIEW OF THE LITERATURE

Dietary Fat and Health

The nutritional quality of the food has emerged as a topic of increasing concern to consumers, producers, researchers and government agencies. Interest in the proposed relationship between dietary fat and development of coronary heart disease (CHD) exemplifies this concern.

Cardiovascular diseases account for over 50% of all deaths in the United States (McNamara, 1986). Although the causes are complicated and probably due to a combination of factors, the type and amount of dietary lipids have been implicated as contributing to atherosclerosis or plaque formation in the blood circulatory system (Winston, 1981). The involvement of dietary lipids in coronary heart disease is believed to be related to three primary factors: (1) the number of total calories contributed by dietary fat is thought to be associated with obesity and the accompanying higher incidence of heart disease, as well as the atherogenic effects of high fat diets per se (Senate Select Committee, 1977); (2) animal fats contribute appreciable amounts of dietary cholesterol which may influence blood serum levels and, thus, favor plaque formation in the circulatory system (Anderson et al., 1957; Keys et al., 1965; Grande et al., 1974); and (3) animal fats have a greater ratio of saturated to unsaturated fatty acids than vegetable fats which would also tend to increase blood serum cholesterol levels (Conor et al., 1961; Keys et al., 1965; Mattson and Grundy, 1985).

The dietary factor best known for its effects upon lipid metabolism in animal is cholesterol (Connor and Connor, 1972). Cholesterol rich diets have regularly caused hypercholesterolemia and atherosclerosis in a large number of species of experimental animals (Armstrong et al., 1970; Kritchevsky et al. 1971; Shireman et al., 1983). Observational epidemiological studies have established that the higher the plasma total or low density lipoprotein cholesterol level, the greater the risk that CHD will develop (Keys et al., 1972). Recently, the Lipid Research Clinics Coronary Primary Prevention Trial has shown that lowering of serum total cholesterol and low density lipoprotein (LDL) cholesterol was followed by a significant reduction in the incidence of CHD and death (Lipids Research Clinic Program, 1984 a, b).

Not all evidence relative to the role of cholesterol in heart disease is related solely to dietary effects of lipids upon cholesterol levels in the blood serum, since the possible cardiotoxicity of cholesterol oxidation products has been suggested by Taylor et al. (1979) as playing a role in CHD. According to this theory, the oxides of cholesterol produce debris in the heart and aorta which may then lead to plaque formation in the circulatory system. This work suggested that pure cholesterol had no effect upon the circulatory system of guinea pigs, whereas the oxides of cholesterol were toxic. The significance of this finding has not yet been verified using human subjects.

A decisive effect of cholesterol in the diet of man upon the serum lipid levels has been clearly demonstrated in a series of experiments being carried out in normal volunteers (Beveridge et al., 1959;

Steiner et al., 1962; Connor et al., 1969). Many reports have shown that the fat content of the diet plays a central role in the regulation of the serum cholesterol level in man and that a simple reduction in the fat content of the diet often produces a prompt fall in the serum cholesterol concentration (Keys et al., 1957; Anderson et al., 1957; Grundy, 1986). On the other hand, an increase in polyunsaturated fatty acid consumption has been shown to reduce plasma cholesterol. Several studies have demonstrated that polyunsaturated fatty acids derived from vegetable oils will reduce plasma cholesterol levels (Kinsell et al., 1952; Ahrens et al., 1957; Anderson et al., 1957; Hegsted et al., 1965; Connor et al., 1969; Shepherd et al., 1980; Phillipson et al., 1985; Mattson and Grundy, 1985).

Kinsell et al. (1952) suggested that it was not simply the amount of fat in the diet, but the type of fat (animal or vegetable) that affects the plasma cholesterol levels. They also reported that animal fat raised plasma cholesterol while vegetable fat lowered it. Ahrens et al. (1957) showed that feeding two vegetable fats (coconut oil and corn oil) led to vastly different plasma cholesterol levels. They also reported a positive correlation between the iodine value of dietary fats and their cholesterol lowering properties. Keys et al. (1957) and Hegsted et al. (1965) concluded that saturated fatty acid have, per gram, about twice as much effect on serum cholesterol levels as do the polyunsaturated fats which act in the opposite direction. Anderson et al. (1957) showed that the incorporation of olive oil or cottonseed oil into a low fat diet produced a significant fall in cholesterol when

compared with the ordinary U.S diet but a less marked reduction than the low-fat diet alone. It seems probable that a greater response is achieved in dietary modification by lowering the saturated fatty acids in the diet, and that this can be potentiated by a partial replacement with polyunsaturated fatty acids (Keys et al., 1957; Hegsted et al., 1965; Shepherd et al., 1980; Connor et al., 1981).

The extent of cholesterol lowering has been related to the magnitude of the difference between the polyunsaturated to saturated (P/S) ratios. Shepherd et al. (1980) using P/S ratio equal to 4 reported a decrease in plasma cholesterol of 23%, while Connor et al. (1981) using a P/S ratio equal to 3.4 reported a cholesterol decrease of 8%. However, Hill and Wynder (1976) reported no difference in serum cholesterol levels with an increase in P/S ratio from 0.3 to 1.2 when a low-calorie, low-cholesterol diet was used.

The mechanism whereby polyunsaturated fat in the diet lowers plasma lipid is unclear. This is largely because the effects of polyunsaturated fat feeding have been deduced from studies which involve replacement of saturated fat with an equivalent amount of unsaturated fat. Two effects then are occurring simultaneously and it has been difficult to discriminate between them (Illingworth et al., 1984). There are a number of possible mechanisms that have been proposed: depression of the very low density lipoprotein (VLDL) and LDL synthesis, better clearance of VLDL and enhanced fecal steroid excretion (Harris et al.,1984; Nestel et al., 1984).

While some researchers have reported that a reduction of risk factors for atherosclerotic disease might occur if the dietary intake of the polyunsaturated fat is increased, others have reported no effect on plasma cholesterol levels or in atherosclerosis if polyunsaturated fat is consumed (McOsker et al., 1962; Erickson et al., 1964). Their experiments, in which oils subjected to varying degree of hydrogenation were studied, indicated no significant effect on serum cholesterol even with substantial changes in the polyunsaturated fatty acid content; however, they used diets with low levels of saturated fatty acids. Mattson and Grundy (1985) reported an identical effect in reducing total cholesterol and LDL-cholesterol when either oleic or linoleic acids was used to feed twenty patients during four weeks; they also reported a lower high density lipoprotein (HDL) cholesterol with the intake of high amounts of linoleic acid. Moreover, Kritchevsky et al. (1971) reported severe damage in the aorta of rabbits fed with peanut oil and attributed this finding to the presence of arachidic acid and behenic acid in the oil. Other researchers have warned about the risk that could be associated with this dietary alteration. Possible harmful effects of dietary w-6 fatty acids include enhanced formation of gallstones (Studervant et al., 1973).

The suspect interrelationships of atherosclerosis with dietary cholesterol and the ratio between saturated and unsaturated fatty acids have led the American Heart Association to recommend that the American public reduce the fat content of the diet, especially the intake of saturated fats, and to limit the daily intake of dietary cholesterol to

300 mg/day (Winston,1981). However, other scientists have questioned the advisability of these recommended changes and indicated that dietary changes for the population as a whole without careful supervision by a qualified physician may be detrimental (Olson, 1981; Reiser, 1981). Reiser (1981) stated that since the relationship between lipid in the diet and CHD has not been well defined, the dietary modification should be recommended only after a person has been diagnosed as hyperlipidemic.

In recent years, there has been a decline in deaths from heart disease in the U.S., perhaps because of better medical attention and improved education (Feinleib, 1984), and possibly also because of changes in edible oil processing and increased consumption of fat from vegetable source (Kinsella, 1981). Overall, the advocacy for the reduction in dietary cholesterol and saturated fats from 40 to 30% of calories, together with an increased intake of unsaturated fatty acids, appears to have had a desirable impact.

Cholesterol and Saturated Fat in Meat Products

Because of their content of cholesterol and saturated fatty acids, animal products have become involved in a controversy concerning their role in the atherogenic process (Kummerow, 1964; Walter and Sherman, 1964). The per capita consumption of animal fats and red meats has declined as the concern about diet and health has grown (USDA, 1984). Red meat has been commonly reported in the literature as "high" in cholesterol, while in fact its cholesterol content on a wet basis averages 60 mg/100 g (Rhee et al. 1982). Meats of all kinds contain cholesterol. It is present both in lean muscle and in the adipose or

fatty tissue. Values reported in the literature for the cholesterol content (wet basis) of beef longissimus muscle (uncooked) ranged from 36-46 mg/100 g (Stromer et al., 1966) to 78.16 mg/100 g (Terrell et al., 1969). Higher values of cholesterol have been reported for separable fat than for separable lean tissue (Rhee et al., 1982; Eichhorn et al., 1986). Rhee et al. (1982) reported that for raw beef steaks the cholesterol content (wet basis) in the fat fraction was greater than 150% of that in the muscle fractions; the difference decreased greatly when steaks where cooked but subcutaneous fat still contained about 122% of the cholesterol content in cooked muscle. Eichhorn et al. (1986) conducted a study to determine cholesterol content of muscle and adipose tissue from young crossbred bulls and steers. They concluded that although sex condition differences within sampling sites were nonsignificant for cholesterol content, it was apparent that meat from steer carcasses may contain more total cholesterol than that from bull carcasses since steers are fatter than bulls when raised under similar condition. Stromer et al. (1966) reported that cholesterol content of both internal and external layers of subcutaneous fat increased with advancing carcass maturity while cholesterol content of the l. dorsi muscle did not change with maturity.

Saturated and monounsaturated fatty acids are predominant in meat fats (Dugan, 1971). About 48% of the fatty acids in bovine fat are saturated (National Live Stock and Meat Board, 1984). Different approaches have been taken to try to increase polyunsaturated fatty acids in meats. Walhstrom et al. (1971) and Villegas et al. (1973)

reported that the amount of unsaturation in pork products was successfully increased by changes in the diets and, thus, it may be a potential source of an increased proportion of unsaturated fat in the human diet. Cook et al. (1970) and Ford et al. (1975) fed ruminant animals with a diet containing a polyunsaturated oil protected from hydrogenation in the rumen by a formaldhyde treated protein. The oil is digested and absorbed from the small intestine and the constituent polyunsaturated fatty acids were deposited into tissues. Under this condition linoleic acid was increased in tissue nearly tenfold over the normal concentration. Meat with elevated levels of linoleic acid produced in this way has been studied in clinical trials in order to provide a diet with normal dietary components but containing higher concentrations of unsaturated fatty acids (Nestel et al., 1973). These researchers reported that increasing unsaturated fats in the diet of cattle lowered plasma cholesterol of subjects on diets containing food products from such cattle. Several disadvantages have been pointed out about this procedure, including increased cost of beef production (Blankenhorn, 1985), and "oily" odor and flavor problems (Ford et al., 1976).

While meat is relatively low in cholesterol and total fat content, meat products such as patties, bologna, frankfurters, etc., range in their fat content from 20 to 30%. Current consumer interest in low calorie foods has led the American Meat Institute to petition USDA for a light standard of identity for cooked sausage. The standard would specify a maximum of 22.5% fat and a minimum of 11.5% protein (Anonymous, 1985). Many meat processors are already reducing the fat

levels in their products because health conscious consumers are avoiding food products that are high in fat (Trout and Schmidt, 1986).

Fat is an important source of certain nutrients and food energy and is added to meat products for economic, flavor and texture reasons (Rakosky, 1970). Any significant reduction in the public's intake of fat from processed meat products will necessarily depend on finding a way to produce such products at a reasonable cost and without loss of palatability or consumer acceptance (Paul and Foget, 1983).

In an attempt to reduce cholesterol in patties, Rhee and Smith (1982) replaced fat with textured soy protein (TSP). They reported a decrease in cholesterol by adding TSP and by decreasing the fat content from 27 to 16% or lower. However, they did not evaluate quality parameters of the final products. Law et al. (1971) reported that consumers preferred ground beef with the relatively low fat content of 15 to 20%, indicating that consumers consider choosing meat that is lower in fat as an alternative. However, data presently do not support the assumption that selecting meat lower in fat will lower fat and cholesterol consumption (Ono et al., 1985; Kregel et al., 1986).

Role of Fat in Meat Emulsion Stability

Sausage products may be generally defined as those products derived from edible flesh alone or in combination with nonflesh protein materials which are ground, chopped, flaked, diced or comminuted and/or seasoned and encased to retain shape or form (Terrell, 1981).

Swift et al. (1961) established that fat incorporated into a sausage product is dispersed in small droplets and enveloped with a layer of protein material, producing essentially an oil in water emulsion in which the interfacial film plays a major role in fat stabilization and the fat droplets always remain globular in a suspension state. Schut (1978) reported that finely comminuted meat products are made by grinding or chopping meat with ice (water) and the addition of salt to form the matrix in which animal fat is dispersed. He also stated that the external or continuous phase in such a system is an aqueous solution of salt and proteins, and at the same time a medium in which insoluble proteins and particles of muscle fiber and connective tissue are dispersed. When fat is incorporated into this matrix, a multiple phase system is formed usually described by meat technologists as a "meat emulsion." Frankfurters belong to this type of meat product. On the other hand this comminuted meat emulsion may be considered a gel type emulsion in which fat is dispersed uniformly in a continuous protein gel matrix (Acton et al., 1982). In a gel type emulsion the fat droplets are physically confined within the protein matrix and thus the shape of the fat droplet does not necessarily remain globular. They may coalesce with each other and form larger droplets, but they cannot escape from the matrix to produce a single phase. It is assumed that stability depends largely on the rigidity of the gel and the distribution of the fat droplets at the beginning of a gel matrix formation (Lee et al., 1981).

Considering the meat emulsion as a particulate composite system, major factors affecting emulsion stability appear to be physical properties of the protein-fat matrix, the fat-protein interaction and the size and distribution of fat droplets.

The capacity of protein to stabilize emulsions of fat has been shown to be as high as 1.61 g of fat per mg protein (Swift et al., 1961). In later work, Swift and Sulzbacher (1963) stated that since this capacity appears far greater than that required to emulsify fat in commercial products in which fat may be incorporated at levels of only 2 or 3 g fat per g protein, the poor retention of fat in commercial products may arise from a fractional use of the binding capacity of the proteins in a raw material.

The primary factors affecting fat phase behavior in a comminuted system are (1) extent of fat release from physically disrupted adipose tissue cells and (2) the total melting characteristics of the fat. Evans and Ranken (1975) showed that, apart from the raw material composition, the heat stability of meat products depends on chopping condition (speed, time and temperature) and on the extent of breakdown of the adipose tissue. Microscopic examination of heat processed sausages showed that under optimal conditions most of the fat cells maintained their integrity despite extensive grinding and chopping (Theno and Schmidt, 1978). After comminution the major part of the fat is dispersed in the mixture as intact cells or cell clusters. Therefore, Brown and Toledo (1975) proposed to discontinue the use of the word "emulsion" and replace it by the term "batter."

It must be noted that stability against fat separation in very coarsely chopped products, such as salamis and some luncheon loaves, is usually not a problem as compared to finely comminuted systems. This may be related to the lack of extensive fat cell rupture, the development of a strong protein exudate in the saline phase at the surface of the coarse lean particles, and the lower end point chopping and mixing temperatures to prevent fat smearing through liquefaction (Acton et al., 1982). Increasing the amount of free fat in the mixture reduces its heat stability (Tinbergen and Olsman, 1979). These workers suggested that the final integrity of fat cells in a sausage batter, rather than the quantity of fat released from ruptured cells, was the determining factor in heat stability. Adipose tissue cell walls are easily ruptured in the grinding of frozen tissue and yield a greater possibility of eventual fat separation when compared to fatty tissue ground or chopped in the thawed or fresh-chilled state; therefore the cellular structure of fat when minced or ground will depend on its history and initial temperature. Specifications for formulating and processing emulsion type sausage products, such as frankfurters, include those designed to assure stability when the products are heat processed. Content of fat and the maximum temperature to be attained during comminution are among factors considered important. While the properties of meat fats are known to affect emulsification, the effects of variations in emulsion stability and processing requirement are not well understood. Townsend et al. (1968) investigated the melting characteristics of meat fats to determine how much melting occurs during comminution and whether this bears a relation to emulsion

stability. The results indicated that there were two primary ranges of melting in beef and pork fats, whether in the raw material or in the raw and cooked emulsions. The ranges where from 3 to 14°C and from 18 to 30 C for beef fats, and 8 to 14°C and 18 to 30°C for pork fats. The instability of an emulsion comminuted to more than 18.5°C coincided with the onset of melting of the high-melting portions of fats. Therefore some melting is inevitable when typical meats are comminuted under the usual conditions. These results suggested that the melting characteristics of meat fats could be the basis for differences in the maximum temperatures at which meat formulas should be emulsified. The fact that melting of a major part of the fats began at approximately 18 C appeared especially important, since it was observed that at this and higher temperatures, increasing temperature concurrently increased melting and decreased emulsion stability (Helmer and Saffle, 1963). In later work (Swift et al., 1968), the stability of the emulsions of two series of fractionated beef and pork fat was studied. Meat formulas containing either 12 or 22% of either fraction or of the original fats were comminuted to maximum temperatures ranging from 12.8 to 35°C and the stability of the emulsion determined. All emulsions containing only 12% added fat were stable. The stability of the emulsion containing 22% added fat depended principally on the melting characteristics of the fats. The high-melting fat yielded stable emulsions and low-melting oily fats yielded unstable emulsion, regardless of temperatures attained during emulsification. These results provided insight regarding the importance of content, composition, and melting of fat as determinants of the rate of release

of oily fats and of emulsion stability.

Lee and Toledo (1979) reported that comminution of fish muscle with added salt in a silent cutter resulted in a gel-like texture after steam-cooking and a mushy texture after cooking in the smokehouse at a slow heating rate. However, these unacceptable textural characteristics were overcome by incorporating shortening (medium hard plastic fat) at level of 15% (fat/muscle). In this study no information was given on how the incorporated fat influenced the material properties of fish protein gels. In later work, Lee and Abdollahi (1981) investigated the reason for this improvement. They concluded that the addition of plastic fats reduced the weakening of textural strength resulting from cooking at the critical temperature zone (70-95^{o}C). Lee et al. (1981) examined meat emulsions by light microscopy to determine the relationship between structure and stability of emulsions prepared either by varying chopping temperature or by adding soy plastic fats of different hardness. They observed formation of fat channels in uncooked emulsions prepared with beef fat at a chopping temperature of 26^{o}C or with soft plastic fat at 16^{o}C. Such fat channel formation caused discontinuity of the protein matrix and led to fat separation during cooking and weakening the textural strength of products. They concluded that changes in fat globule size and distribution as affected by melting properties or hardness of fats are clearly reflected by changes in emulsion stability. Their results suggested that emulsion stability is determined largely by the physical properties of protein matrix and fat incorporated.

With most pork and beef fat formulations, a final comminution temperature of 16 to 18°C is used, whereas a maximum of 10 to 12°C is used for poultry meat products. This end point temperature appears to be linked directly to the general fat characteristics previously mentioned. The majority of studies with comminuted meats are conducted with meat blends leaving a considerable unknown area for quantifying these characteristics (Acton et al., 1983).

Fat characteristics such as the solid-liquid ratio, solid consistency and liquid viscosity at specific temperatures, heats of fusion and transition, and melting temperature ranges are controlled by the ratio of the saturated to unsaturated fatty acids and their polymorphic property. The lower the ratio of saturated to unsaturated fatty acids, the lower the apparent melting point of the fat and, consequently, less heat is required to reach adequate fat dispersion.

The occurrence of emulsion destabilization is rare in a routine meat packing operation. Nevertheless, emulsion destabilization still remains one of the concerns in the meat processing industry, especially when new sources of ingredients are incorporated or when inevitable changes in the processing system occur. In those situations stable emulsions may be not obtained under the conventional processing system unless the underlying physical changes are carefully taken into consideration in formulation and processing (Lee et al., 1981).

Reducing the fat content in wieners has been reported to increase toughness (Sofos and Allen, 1977; Paul and Foget, 1983; Foegeding and Ramsey, 1986). Sofos and Allen (1977) substituted textured soy protein for fat to produce an acceptable low fat wiener. However, they found that wieners high in soy and low in fat showed increased shrinkage

losses during heat processing. Foegeding and Ramsey (1986) investigated the effect of replacing fat with water or water-gum suspensions on the cooking stability, textural and sensory properties of meat batter. They concluded that even though some gums appeared to help hold moisture in the cooked product the difference in texture still persisted. However, sensory evaluation indicated that the significant variation in texture did not have a significant influence on hedonic scores and that all low-fat treatments were as acceptable as control frankfurters. John et al. (1986) investigated sensory and physical attributes of frankfurters prepared using lean and fat from pigs fed with canola oil to increase the monounsaturated to saturated lipid ratio. Frankfurters with 25% fat were compared to control frankfurters with 30% fat. Even though the sensory evaluation indicated that the overall palatability ratings of the test frankfurters were similar to the control product, instron texture analysis indicated slight increases in cohesiveness for those with elevated monounsaturated to saturated lipid ratios. Decreasing fat also increased gumminess and chewiness. Thus production of a low-fat frankfurter requires altering currently used formulations and processes so that flavor, color, and texture are as acceptable as current products.

While limited information is available concerning the effect of vegetable oil on the stability of meat emulsions, no information is available concerning the effect of oil addition on the quality characteristics of the final products (color, texture, flavor, juiciness, shelf-life, and nutritional parameters such as polyunsaturated to saturated fatty acid ratio and cholesterol content).

MATERIALS AND METHODS

Experimental Design

A 3x2x2 factorial design (Figure 1) was used to compare three final fat levels (12, 20, 29), two levels of peanut oil substitution for beef fat (0 or 60%) and two storage periods (fresh or 6 weeks in vacuum packaging at 4°C). The 60% substitution of oil for beef fat was the maximum substitution possible particularly in the 12% final fat content, since the intramuscular fat cannot be physically removed. All treatment groups were prepared in triplicate in 11.36 kg batches.

Ingredients and Formulation

An entire carcass from a young bull was boned at 72 hr postmortem. Trimmable fat was removed to obtain a lean portion visually standardized to 95-5 (%lean- %fat). The fat trimmings were obtained from steer carcasses and was visually standardized to 20-80. Lean and fat sources were kept separated, coarse ground though a 12.7 mm plate and fine ground through a 3.2 mm plate using a Holly Matic grinder (Model GMG 150). Representative samples for fat, moisture and protein determination were obtained. Raw material needed to produce a 11.36 kg batch were placed into plastic bags and frozen at -30°C for about 30 days.

Commercial peanut oil was used as a source of polyunsaturated fat. It was kept under refrigeration.

Fat levels, %	12		20		29	
Oil Substitution, %	0	60	0	60	0	60
Storage	F S	F S	F S	F S	F S	F S

F = Fresh.

S = Storage (six weeks storage at $4^{o}C$).

Figure 1. Experimental design.

All meat wiener or bologna seasoning (Heller BU-0032, B. Heller and Company, Chicago), composed of salt, corn syrup solids (35.4%), mustard (16.7%), spices extractives on a dextrose carrier and sodium erythorbate (0.52%), with not more than 2% tricalcium phosphate and tetrasodium pyrophosphate added to prevent caking was used. A commercial cure (6.25% NO_2) at the level of 0.20% was added as a curing ingredient. Ice and cold water were used as a source of added water.

Once the proximate analysis for fat and lean meat were determined and smokehouse yield (100%-12% loss in smokehouse) calculated, a least cost microcomputer software formulation was used to determine the quantity of ingredients to be used in each formulation. The following restrictions were used: final fat content of 12, 20 or 29% and final moisture content of 4 x protein content + 9% added water. Table 1 contains the ingredient formulations required to manufacture the different treatment combinations.

Frankfurter Manufacture

Due to the instability observed in the meat emulsion when peanut oil was added as a source of fat, preliminary experiments were conducted to optimize the processing procedure. Based on these preliminary experiments the standardized processing procedure was as follows: after thawing ($0^{o}C$) the lean ingredient for 48 hr and the fat ingredient for 24 hr, the lean portion was mixed with the spices, curing ingredients and half of water in a Leland "Double mixer" Food Mixer (Model L 100 DA) for 1 min. Then, beef fat, peanut oil and the remainder of the water and ice were added to the mixer and mixed for

Table 1. Formulation ingredients for a 11.36 kg batch of the different treatment combinations

Ingredients	Oil					
	0			60		
	Final fat content, %			Final fat content, %		
	12	20	29	12	20	29
Lean	7.11	6.18	4.71	7.39	6.45	5.38
Beef fat	1.25	2.45	3.81	0.19	0.71	1.30
Oil	0.00	0.00	0.00	0.82	1.36	1.98
Seasoning	0.55	0.55	0.55	0.55	0.55	0.55
Water	2.43	2.35	2.25	2.37	2.25	2.12

two more minutes (final temperature was in the range 0 to 1.1°C). The blended material was transferred to a Stephan Microcut emusifier (Model # MVB KB) and passed three times through a blank plate, twice through a 1.5 mm plate and twice through a 1 mm plate. The final temperature of this emulsified batter was <13°C. The emulsified mixture was transferred into a Vemag Robot 500 stuffer (Model TYP 128) where the products were stuffed under vacuum into 25 mm cellulose casing and linked automatically at every 125 mm.

All the batches were weighed separately before the product was smoked and cooked in a Vortron smokehouse (Model # 500). The smoking cycle was as follows: 20 min at 54.4°C with smoke, 20 min at 60°C and 38% relative humidity with smoke, 20 min at 71.1°C and 42% relative humidity, and then at 76.7°C and 42% relative humidity until the internal temperature of the product was 68.9°C. The frankfurters were showered for 15 min, weighed and chilled (2°C) for 24 hr. After chilling the frankfurters were weighed again and the links were then peeled and vacuum packaged. Half of them were analyzed as a fresh product and half of them were stored at 4°C for 6 weeks and then analyzed.

Emulsion Stability

Emulsion stability was performed by the test developed by Townsend et al. (1968). Three 34 g samples of raw emulsion from each treatment were placed into polycarbonate tubes (2.22 cm x 10.16 cm) which were stoppered and heated to 69°C in a water bath preheated to 49°C with gradual raising of the temperature to 70°C. The separated material was collected in graduated 15 ml centrifuge tubes and the volume of

water and fat released in each tube was determined from interfaces. Emulsion stability was expressed as the average milliliters of fat and water released per 34 g emulsion.

Chemical Analysis

Percentages of fat, protein, moisture, and cholesterol, fatty acids profiles and TBA (thiobarbituric acid) values were determined for raw material (fat and lean portion) and in all final cooked products. Phytosterol was determined for peanut oil. Fat, protein and moisture were determined using Foss-let, Kjeldahl and oven drying standard methods (AOAC, 1980), respectively.

Cholesterol Analysis

Cholesterol was analyzed by extracting total lipids using the Folch et al. (1957) procedure. The extracted lipid was saponified (Rhee et al., 1982) by mixing 0.125 g of the extracted fat with 5 ml of 15% KOH (in 90% ethanol) and heating in a water bath at 88°C for 30 min. Then, 5 ml of distilled water were added and the saponified solution was cooled to room temperature. The unsaponifiable material was extracted twice with 10 ml of hexane for each extraction. A nitrogen stream was used to evaporate the solvent from 4 ml of the hexane extract. Cholesterol in the unsaponifiable fraction was determined by colorimetric method using the Fisher Diagnostics Total Cholesterol Kit procedure. Duplicate aliquots (0.025 ml each) of the sample were placed in test tubes, and 1.5 ml of S R Direct Cholesterol reagent was added to each tube. A blank and a standard were prepared along with the sample. After mixing, test tubes were placed in a

37°C water bath for 20 min, mixed again and absorbance was measured at 625 nm in a Perkin Elmer Lamda 3 UV/VIS Spectrophotometer. Cholesterol content was calculated by comparing the absorbance of the sample against the absorbance of a known standard. Since the colorimetric method did not discriminate between cholesterol and phytosterol, the final cholesterol content was determined by substracting the phytosterol content provided by the amount of oil used in each treatment.

Phytosterol Analysis

Phytosterol content in peanut oil was determined using the same saponification and colorimetric procedures that were used for cholesterol analysis in frankfurters as previously outlined.

Fatty Acid Analysis

Frankfurters, fresh and after six weeks storage, and emulsions were sampled to determine the effect of different fat content, oil, cooking and storage condition on the fatty acid profile. Raw materials (fat, lean and oil) were also analyzed for fatty acid content. Lipids were extracted using the Folch et al. (1957) procedure as follows: 25 g of sample in duplicate were blended with 225 ml of 20:1 chloroform:methanol for 10 min in a Waring blender jar. The slurry was filtered (Whatman No 2 filter paper) by suction into a 500 ml side arm flask. The filtrate was transferred to a 500 ml separatory funnel, 40 ml of cold distilled water were added, the mixture shaken and let stand for 30 minutes. The bottom chloroform layer was transferred into a flat bottom flask and placed in the roto evaporator to remove chloroform. After the fat was completely dried using a nitrogen

stream, 100 mg of the extracted fat was diluted up to 10 ml with chloroform and then 1 ml, in duplicate, was taken and 0.2 ml Meth-Prep II (0.2 N methanolic solution of m-trifluoruro methyl phenyl trymethylammonium hydroxide) was added and allowed to react for 30 min.

Fatty acids were determined by gas-liquid chromatography performed on a Perkin-Elmer Sigma 3B Dual FID Chromatograph with a 180 cm x 2 mm column packed with 10% SILAR-10 C on 80/100 mesh GAS-CROM Q. Amount injected was 0.001 ml in duplicate. Oven temperature was 175°C, and injector and detector temperatures were 250°C. Nitrogen was used as the carrier gas at 30 ml/min. Retention time and area under the curve were obtained using a Perkin-Elmer LCI-1000 Laboratory Computing Integrator. Calibration curves were determined for all fatty acids by injecting mixtures of the respective methyl esters (Supelco, Co.).

Thiobarbituric Acid (TBA) Analysis

Rancidity development was also monitored by the TBA test for malonaldehyde (MA) using the procedure developed by Tarladgis et al. (1960) and modified by Zipser et al. (1964). A 10 g sample was homogenized with 44 ml cold deionized water, 5 ml of a 0.5% solution of propyl gallate and ethylenediamine tetraacetic acid, and 1 ml of 0.5% sulfanilamide reagent (in 20% HCL solution) for 2 min. The homogenate was transferred to a kjeldahl flask and distilled water was added to complete 100 ml. Dow antifoam A was placed onto the neck of the Kjeldahl flasks to control foaming. The mixture was heated until about 50 ml of distillate was collected. Five milliliters of distillate were added to 5 ml of 0.02M TBA in 90% glacial acidic acid and incubated in boiling water bath for 35 min. The absorbance of the pink solution was read at 532 nm in a Perkin Elmer Lamda 3 UV/VIS Spectrophotometer.

A standard curve was constructed using the MA derivative 1,1,3,3, tetraethoxipropane (TEP, Sigma Chemical Co) which hydrolyzes under acid conditions to form MA (Sinnhuber and Yu, 1958). The recovery of MA was estimated by adding known amounts of TEP (1-5 ml of 10^{-5} M) to the homogenates.

Sensory and Instrumental Analysis

Multiple Comparison Test

Twelve trained sensory panel members were used to evaluate differences among frankfurters, using the multiple comparison test (Larmond, 1970). Training was held prior to actual testing to familiarize the panelist with the procedure. Texture (firmness), juiciness and flavor intensity were evaluated using the scoring scales as shown in Table 2. Frankfurters were warmed by holding them in boiling water for 8 min. Then they were cut in portions of 2 cm each, afterwhich the portions were placed in randomly coded (three digit) polystyrene cups and presented in randomized order to the panelists, along with a reference labeled R. The known reference or standard sample (R) was a frankfurter prepared to resemble a commercial product with a final fat content of 29% and no vegetable oil. At each evaluation three samples were tasted in individual booths under red lighting to mask any difference due to color. The panelists were asked to score the coded sample in comparison with the reference sample. Panelists were asked to cleanse their palate with apple juice warmed to room temperature between samples.

Color difference was evaluated during retail display, under fluorescent natural light, using the scoring scale shown in Table 2. A three digit number was placed in the package and the product was

Table 2. Multiple comparison scoring scale for texture, juiciness, flavor intensity and color darkness characteristics

Description	Score	Description
Texture		Flavor intensity
Extremely firmer than R	9	Extremely more intense than R
Much firmer than R	8	Much more intense than R
Moderately firmer than R	7	Moderately more intense than R
Slightly firmer than R	6	Slightly more intense than R
Equal to R	5	Equal to R
Slightly softer than R	4	Slightly less intense than R
Moderately softer than R	3	Moderately less intense than R
Much softer than R	2	Much less intense than R
Extremely softer than R	1	Extremely less intense than R
Juiciness		Color darkness
Extremely juicier than R	9	Extremely darker than R
Much juicier than R	8	Much darker than R
Moderately juicier than R	7	Moderately darker than R
Slightly juicier than R	6	Slightly darker than R
Equal to R	5	Equal to R
Slightly less juicy than R	4	Slightly lighter than R
Moderately less juicy than R	3	Moderately lighter than R
Much less juicy than R	2	Much lighter than R
Extremely less juicy than R	1	Extremely lighter than R

randomly presented to the panelist along with the reference labeled R. The panelists were asked to score the coded sample in comparison with the reference sample.

Overall and Color Acceptability

A hedonic rating scale (Table 3) was used to determine the acceptability level of each different treatment. Frankfurters were evaluated by a 120 member consumer sensory panel. For overall acceptability evaluation, frankfurters were warmed by holding the product in boiling water for 8 min, cut in portions of 2 cm each, placed in randomly coded (three digit) polystyrene cups, and presented in randomized order to the panelists along with ketchup and mustard. Color acceptability was evaluated during retail display. For both overall and color acceptability evaluations, panelists were asked to indicate how much they liked or disliked each of the products.

Rancid Flavor

Rancid flavor development was evaluated weekly by holding the product in vacuum packaging at $4^{o}C$ for a six weeks storage period. A twelve member trained panel was used to evaluate rancid flavor at one week intervals throughout the six weeks period. Coded samples were served warmed and panelists were asked to score rancid flavor on the numerical scale shown in Table 4.

Instron Textural Analysis

Shear stress, as a measurement of "tenderness," was conducted on ten room temperature frankfurter samples per treatment (fresh and after six weeks storage at $4^{o}C$). Tenderness was expressed as the force (g) required to shear the sample perpendicular to its long axis using a

Table 3. Hedonic scoring scales used for overall and color acceptability evaluation

Description	Score
Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

Table 4. Scoring scale for rancid flavor evaluation of frankfurters during six weeks storage

Rancid flavor	Score
None	1
Barely perceptible	2
Perceptible	3
Slightly strong	4
Moderately strong	5
Very strong	6
Extremely strong	7

double shear blade device (Mohsenin, 1978), which was attached to an Instron Universal Testing Machine (model TM). The double blade device was placed on the top of a compression cell (CCT). The sample was placed in the hole of the device and the crosshead was lowered until it came in contact with the top of the device. The measurements were obtained by reading the maximum force necessary to cut the sample transversely. The crosshead speed was 2.2 cm/min and the recorder chart speed was 11 cm/min. The attenuation used was 9.09 kg. Because it was a double blade device, force was divided by twice the area of the frank. Shear stress was expressed as g/cm^2.

Instrumental texture profile of the final product (fresh and after six weeks storage at 4^oC) were determined using an Instron Universal Testing Machine as described by Bourne (1978). Ten 13 mm long cylindrical samples (at room temperature) were evaluated for each sample. Each sample was compressed twice longitudinally to 75% of its original height by a two-cycle compression test. Force-time deformations were obtained at a crosshead speed of 2.2 cm/min and chart speed of 11 cm/min. The attenuation used was 18.18 kg.

Textural parameters of force to fracture (kg), hardness (kg), first and second-cycle area (cm^2), and springiness (cm) were measured directly from the force-time curves. To obtain the actual springiness values, springiness distance in cm was corrected by the ratio of crosshead speed/ chart speed. The others parameters were determined as follows:

Cohesiveness = A2/A1, where A2 and A1 are the areas of the second and

first cycle, respectively

Gumminess = hardness x cohesiveness

Chewiness = gumminess x springiness

Hunter Color Analysis

Surface and internal color of the finished frankfurters were evaluated objectively with a Hunter Lab D25-2 Color Difference Meter (Hunter Associates Laboratory, Inc., Fairfax, Va.). The instrument was standardized using a white ceramic tile certified with standard values of "L" (lightness) = 92.18, "a" (redness) = -1.1, and "b" (yellowness) = 0.4. These Hunter color values (L, a, and b) were determined for ten samples per treatment. Hunter color values of "a" and "b" were used to calculate hue angle ($\tan^{-1}$ b/a) and saturation index $[(a^2 + b^2)^{1/2}]$.

Rabbit Study

White New Zealand male rabbits, weighing approximately 2.40 kg, were randomly divided into five groups of three animals each. Each rabbit was housed in a stainless steel cage under controlled environmental conditions and maintained on the diet shown in Table 5 for six weeks. Based on preliminary experiments, animals were fed as follows: during the first and second weeks, all five groups were fed with commercial rabbit chow and initial cholesterol and triglyceride plasma levels were determined during this time; at the third week, each rabbit received 5 g of its respective treatment; at week four, the ration was increased to 7.5 g, and during the last two weeks (fifth and sixth), 10 g were provided. Commercial rabbit chow and water were

Table 5. Composition of diets

Treatments[a]	Diets
12-Ø	Chow + franks (12-0%)
12-6Ø	Chow + franks (12-60%)
29-Ø	Chow + franks (29-0%)
29-6Ø	Chow + franks (29-60%)
CONTROL	Commercial rabbit chow

[a]Treatments were as follows: 12-Ø = commercial chow + franks with 12% final fat content; 12-6Ø = commercial chow + franks with 12% final fat content, 60% of which was peanut oil; 29-Ø = commercial chow + franks with 29% final fat; 29-6Ø = commercial chow + franks with 29% final fat, 60% of which was peanut oil; CONTROL = commercial chow only.

provided ad libitum during the trial.

Blood samples were collected from the marginal ear vein each week. Measurement of total serum cholesterol was made by colorimetric method using the Fisher Diagnostic Total Cholesterol Kit procedure as follows: 0.025 ml of the blood serum in duplicate were placed in test tubes, 1.5 ml of SR Direct Cholesterol Reagent were added to each tube, the solutions were mixed and held in a 37°C water bath for 20 minutes. A blank and a standard were prepared along with the sample. After mixing, the absorbance was measured at 625 nm in a Perking Elmer Lamda 3UV/VIS Spectrophotometer. Cholesterol content was calculated by comparing the absorbance of the sample against the absorbance of the known standard. Measurements of total serum triglycerides were made by enzymatic assay (Sigma, St. Louis, MO, USA) as follows: 1 ml of the triglyceride reagent was prewarmed at 37°C, 0.010 ml of the sample was added, and the solution was mixed and incubated at 37°C for exactly 10 minutes. A blank and a standard were prepared along with the sample. After mixing, the absorbance was measured at 500 nm in a Perkin Elmer Lamda 3 UV/VIS Spectrophotometer. Triglyceride content was calculated by comparing the absorbance of the sample against the absorbance of the known standard.

Statistical Analysis

The design consisted of a 3x2x2 factorial arrangement with the factors being final fat content at 3 levels (12, 20, and 29%), peanut oil substitution at 2 levels (0 and 60%), and storage condition at 2 levels (fresh and 6 weeks storage). In some comparisons heat treatment at 2 levels (emulsion and cooked product) was utilized. Data collected

from this study were analyzed using SAS PROC GLM (1985). Pairwise comparisons of treatment means were performed using the least significant difference (LSD) and Duncans' Multiple Range test (1955) procedures.

Simple linear regression was used to determine the relationship between diet and serum cholesterol or triglyceride response in rabbits. Comparisons of the slopes of the regression equations were performed using the procedure discussed by Draper and Smith (1981). Significance was determined by the F-test and differences were declared at the 5% level of probability.

RESULTS AND DISCUSSION

Processing Characteristics

The mean values of different levels of peanut oil substitution and final fat content for emulsion stability and smokehouse yield are shown in Table 6. No differences ($p>0.05$) were observed in fat released because of either oil substitution or final fat content. Significant differences ($p<0.05$) were observed in emulsion stability when expressed as milliliters of water released, and in smokehouse yield due to the final fat content but not to the oil substitution. These results indicate that as the final fat content percentage decreased from 20 to 12% the water released increased and the cooking yield decreased.

Reducing the fat content in wieners has been reported to decrease cooking yield (Sofos and Allen, 1977; Wallingford and Labuza, 1983). Sofos and Allen (1977) substituted texture soy protein for fat to produce acceptable low fat-weiners. However, they found that weiners high in soy and low in fat showed increased shrinkage losses during heat processing. Wallingford and Labuza (1983) added gums at levels of 0.2% to prevent water loss from a low-fat meat emulsion and reported that xanthan gum was more effective in helping to hold water than locus bean and carrageenan gums. Acton et al. (1983) stated that in order to have significant water retention in meat products, most of the myofibrillar protein structure must be dissociated. In addition, they indicated that this dissociation is determined to a large extent by the effective salt concentration which is essentially the concentration of

Table 6. Mean values for processing characteristics by final fat content and oil treatments

Characteristics	Treatments				
	Final fat content, %			Oil,[a] %	
	12	20	29	0	60
Emulsion stability[b]					
Fat, ml	0.25	0.21	0.25	0.23	0.25
Water, ml	4.38[x]	2.95[y]	2.80[y]	3.49	3.26
Smokehouse yield, %					
After cooking	86.60[x]	88.54[y]	89.82[y]	88.06	88.18
After chilling	85.52[x]	87.22[y]	88.22[y]	86.88	87.08

[a]Oil treatments were as follow: 0 = No peanut oil; 60 = 60% of the final fat content was peanut oil.

[b]Each fraction measured as ml lost per 34 g emulsion.

[x,y]Means on a row and within a treatment group bearing different superscripts differ significantly ($p<0.05$) as indicated by LSD procedure. Total number of observations was 18. Final fat means are based on 6 observations, while the oil means are based on 9 observations.

salt in the aqueous phase. Acton et al. (1983) also stated that the viscous sol (protein in water) that is formed during emulsification is later transformed during cooking into a viscoelastic gel network where water interacts with protein and the fat particles are entrapped within the network matrix.

It can be observed (Table 1) that when low fat products were formulated, an increase in the aqueous phase (total moisture added) and an increase in the lean portion (total amount of myofibrillar proteins) were required to achieve the added water limit of 4 x protein % + 9%. These increases in both water and lean would reduce the total effective salt concentration. Since the same time of emulsification was conducted for all of the treatments, it is possible that those treatments with a higher amount of lean retain a large portion of the myofibrillar structure. Under this condition the protein would remain aggregated and less possibility of water binding would be encountered. Consequently, it could be speculated that protein-protein interaction predominated over a protein-water interaction and the water may have been squeezed out of the matrix network. The most important attribute responsible for the emulsifying properties of the proteins is their ability to diffuse toward and adsorb at the oil-water interface. It is generally assumed that once a portion of a protein has contacted the interface, the nonpolar amino acid residues orient themselves toward the nonaqeous phase and the free energy of the system decreases, and the remainder of the protein adsorbs spontaneously. During adsorption, most proteins unfold extensively and, if a large surface is available, spread to a monomolecular layer (Kato and Nakai, 1980). If this is true, protein in a mixture with higher fat content would have more

possibility to unfold and as the proteins unfolded more water binding sites may be opened creating greater water retention. Consequently, a low fat emulsion would have the disadvantage of having less unfolded protein which may reduce moisture retention during cooking.

Trout and Schmidt (1986) investigated the effect of the effective salt (NaCl) concentration on the water binding ability (WBA) of emulsion-type products with two levels of fat (5 and 30%). They reported that when compared at the same effective salt concentration, fat level had little effect on WBA. However, their cooking procedure was different than the one used in the present study. They stuffed the products in a can and cooked the product in a retort, providing a closed cooking environment where it would be expected that an equilibrium of the relative humidity of the environment and the product would be produced and, consequently, no additional humidity was lost from the product. According to this finding, it seems probably that the results obtained by Trout and Schmidt (1986) could be influenced by the type of cooking along with the effectiveness of salt concentration. However, they did not use the normal smokehouse cooking procedure with which to compare these results. It is obvious that more research needs to be done in this area to fully understand the behavior of the myofibrillar protein when low fat meat emulsions are formulated.

The presence of oil did not show any effect either on the water released during the emulsion stability test or on the smokehouse yield ($p>0.05$). In addition, no significant interaction was detected between fat content and oil substitution treatments.

Chemical Composition

Proximate Composition

Mean values for proximate composition expressed as percentage of moisture, fat and protein of the final product are shown in Table 7. Significant differences ($p<0.05$) in protein, fat and moisture content were observed in the products due to the final fat content treatments. These differences were expected since products were formulated to have different fat content. The significantly higher protein content in products with 12 and 20% final fat content is a consequence of reducing fat levels. As it can be observed in Table 1, as the final fat content was decreased a concomitant increase in the lean portion was required. The significantly higher moisture content in products with lower fat content was due to the increase in protein content which allowed for more moisture based on the regulation for added water (4 x %Protein + 10%). Products were formulated to have 9% added water. The final added water decreased ($p<0.05$) as the final fat content decreased (Table 7). This is explained by the lower yield (greater cooking loss) observed in low fat products during smokehouse cooking. This observation indicated that at a low fat, high protein content, proteins were not able to retain the moisture and maintain the same ratio of protein to water as in high fat, low protein products.

No differences ($p>0.05$) in protein, fat and moisture content were observed in the product due to the oil levels. The lack of difference in the proximate composition due to the oil levels was expected since oil was added to substitute for part of the beef fat and the final fat content was formulated to remain the same. On the other hand, due to

Table 7. Mean values for proximate composition of frankfurters by final fat content and oil treatments

Characteristics, %	Treatment comparison				
	Final fat content, %			Oil, %[a]	
	12	20	29	0	60
Protein	14.80[x]	13.06[y]	11.05[z]	13.00	12.94
Fat	12.29[x]	20.01[y]	28.99[z]	20.31	20.55
Moisture	65.28[x]	60.02[y]	53.29[z]	59.29	59.76
Added water	6.08[x]	7.78[y]	9.09[z]	7.29	8.01

[a]Oil treatments were as follows: 0 = No peanut oil; 60 = 60% of the final fat content was peanut oil.

[x,y,z]Means on a row and within a treatment group bearing different superscripts differ significantly ($p<0.05$) as indicated by LSD procedure.

the lower melting point of the peanut oil when compare with beef fat, the processing procedure was standardized during preliminary experiments to avoid final unstable products with excessive moisture loss and fat rendering out of the final product during cooking.

Fatty Acid Profiles

The results of the fatty acid profile analysis of the different frankfurter treatments are shown in Table 8. It can be observed that the final fat content treatment had no effect on the individual fatty acid profile expressed as a percentage of the total fatty acids present. This result may be explained by the use of common beef fat and peanut oil sources and in all the cases peanut oil was substituted for beef fat at the fixed level of 60%. Significant differences ($p<0.05$) were observed in the fatty acid profiles due to the peanut oil content. Products with 60% oil substitution were higher ($p<0.05$) in oleic and linoleic fatty acids and lower in myristic, palmitoleic, palmitic and stearic acid, when compared to the treatment without oil substitution. Overall, an increase in polyunsaturated fatty acids, a decrease in saturated fatty acids and, consequently, an increase in the ratio of the polyunsaturated to saturated (P/S) fatty acid ($p<0.05$) were observed when peanut oil was used to substitute for 60% of beef fat (Table 9).

Peanut oil is relatively high in linoleic acid (30.33%) and low in palmitic (10.01%) and stearic (3.31%) acid content (Table 10). Thus, the increase in the ratio of P/S in products with 60% peanut oil would be expected. Different approaches have been evaluated to increase the P/S ratio in meat and meat products. Ford et al. (1975) fed ruminant

Table 8. Mean values for fatty acid profile of frankfurters by final fat content, oil, heat and storage treatments

Fatty acids[b]	Treatments[a]								
	Final fat content, %			Oil, %		Heat		Storage	
	12	20	29	0	60	E	C	F	S
Myristic	2.98	3.08	3.24	4.44^{x}	1.76^{y}	3.08	3.12	3.12	3.38
Palmitic	20.32	20.19	19.88	24.23^{x}	16.03^{y}	20.26	20.01	20.01	19.00
Palmitoleic	4.61	4.59	4.41	6.42^{x}	2.66^{y}	4.58	4.49	4.49	4.52
Stearic	12.14	11.73	11.49	15.22^{x}	8.36^{y}	11.76	11.82	11.82	11.82
Oleic	42.74	42.82	43.59	40.83^{x}	45.27^{y}	43.01	43.96	43.96	43.04
Linoleic	10.42	10.46	10.53	3.17^{x}	17.77^{y}	11.00	10.37	10.37	10.66
Linolenic	2.08	1.95	2.09	1.95	2.13	2.46	1.97	1.97	2.03
Arachidic	2.13	1.92	1.70	1.92	1.99	1.99	1.80	1.80	2.03
Lignoceric	0.86	0.90	0.94	0.90	0.92	0.92	0.88	0.88	0.83

[a]Oil treatments were as follow: 0 = No peanut oil; 60 = 60% of the final fat content was peanut oil. Heat treatments were as follow: E = Emulsion (not heat treated); C = Cooked product (cooked up to 68.9°C internal temperature). Storage treatments were as follows: F = fresh, determination was made four days after being prepared; S = storage, determination was made after six weeks of vacuum packaged storage at 4 °C.

[b]Fatty acids were expressed as percentages of the total amount of fatty acids.

[x,y]Means on a row and within a treatment group bearing different superscripts differ significantly ($p<0.05$) as indicated by LSD procedure. Total number of observations was 36. Final fat means are based on 12 observations, while oil, storage and heat means are based on 18 observations

Table 9. Mean values for total fatty acid types by oil treatments

Types,%	Oil, %[a] 0	60
Total saturated	43.89[x]	29.09[y]
Monounsaturated	47.25	47.93
Polyunsaturated	4.94[x]	19.68[y]
Polyunsaturated/saturated	0.11[x]	0.68[y]

[a]Oil treatments were as follow: 0 = No peanut oil; 60 = 60% of the final fat content was peanut oil.

[x,y]Means on a row bearing different superscripts differ significantly ($p<0.05$) as indicated by LSD procedure. Oil means are based on 9 observations.

Table 10. Mean values for fatty acid profiles of raw materials

Fatty acid[a]	Raw material		
	Beef fat	Bull lean	Peanut oil
Myristic	4.80	4.35	---
Palmitic	23.71	22.31	10.01
Palmitoleic	6.82	7.22	---
Stearic	16.21	18.66	3.31
Oleic	40.72	37.70	47.80
Linoleic	3.51	4.62	30.33
Linolenic	1.98	2.55	2.02
Arachidic	---	---	3.37
Lignoceric	---	---	1.65

[a]Fatty acids were expressed as a percentage of the total amount of fatty acids present.

animals a diet containing a polyunsaturated oil protected from hydrogenation in the rumen. Under these conditions linoleic acid was increased nearly tenfold over normal concentration. John et al. (1986) fed pigs with canola oil, which is high in oleic acid, and then used lean and fat from these animals to formulate frankfurters. They were able to produce products with a maximum of 18.6% less saturated fat when compared with the control (a commercial-like product). While these methods had achieved their goal of increasing the P/S ratio, several disadvantages have been pointed out such as increased cost of production (Blankenhorn, 1985) and oily and flavor problems with the lean and fat of the carcasses from those animals (Ford et al., 1976; John et al., 1986). The direct addition of peanut oil during the manufacture of the product has the advantage of avoiding the production of carcasses with oily fat and flavor problems. In addition, the increase in the P/S fatty acid ratio from 0.11% to 0.68% (Table 9) may be of advantage to a certain portion of the population interested in increasing the amount of polyunsaturated fat in their diet. The consumption of products with high levels of polyunsaturated fatty acids and low levels of saturated fatty acids along with low total fat content have been recommended by the American Medical Association (Winston, 1981). There was an increase in percentage of oleic and a decrease in palmitoleic acid when peanut oil was added to the frankfurter manufactured in this study. There was no difference ($p>0.05$) in the total monounsaturated fatty acid content due to the oil treatments (Table 9).

Mean values for fatty acid profile as affected by heat and storage condition are presented in Table 8. Results indicated no difference ($p>0.05$) in the fatty acid profile due to heat or storage conditions. Heat and storage induced changes in fatty acids of foods have been studied for some time. Giam and Dugan (1965) determined the fatty acid composition of lipids of beef, pork, and lamb in raw meat and in the meat after cooking in boiling water for 30 minutes. They found essentially no change that could be attributed to cooking. Terrell et al. (1967) found that cooking decreased the unsaturated/saturated fatty acid ratio of subcutaneous fat from loin steaks and Terrell et al. (1968) reported less linoleic acid in neutral fat from broiled longissimus steaks than in raw steaks. Lumen et al. (1974) studied the effect of roasting fresh pork on the fatty acids of separable porcine tissue. They reported no appreciable change in the fatty acids when the pork was cooked to an internal temperature of 82°C. A major difference between these studies and the present study was that in all cases in the previously mentioned experiments the fat was directly exposed to the heat which produced a more severe effect when compared with the type of cooking used in the present study. On the other hand, in an emulsion type product, like frankfurters, the fat is encapsulated in a gel-type matrix that may prevent drastic effects and consequently, major changes in the unsaturated fatty acid content.

A decrease in the levels of polyunsaturated fatty acids due to refrigeration or frozen storage has been reported in chicken (Moerck and Ball, 1974) and in model systems of beef and poultry (Igene et al., 1980). However, such changes in the intact muscle of lamb (Lazarus et al., 1977) and beef (Kunsman et al., 1978) have been small or

nonexistent. Misock et al. (1979) manufactured bologna in which 20% of the lean beef was replaced with mechanically deboned meat. They reported no loss of fatty acid during storage. The reasons for the lack of change in fatty acid composition in meat products during storage vary. Moerck and Ball (1974) showed that fatty acids must have three or more double bonds to be very susceptible to oxidation during refrigerated storage of muscle food, and that the susceptibility increases with the number of double bonds in the fatty acid. Lee et al. (1975) suggested that at a high linoleic/hemoprotein ratio the hemoproteins act as prooxidants but as the ratio falls below 350 they increasingly become antioxidants. In fact, at low ratios of 90:1 the hemoprotein seem to exert strong antioxidant activity.

The lack of changes during heating and storage found in the unsaturated fatty acids content in this study may be explained by the presence of linoleic acid (a fatty acid with only two double bonds) as a major polyunsaturated fatty acid and by the presence of antioxidants like nitrites, phosphates and ascorbates that were added in the formulation.

Cholesterol

Cholesterol contents of the frankfurters are shown in Table 11. A significant interaction ($p<0.05$) between final fat content and peanut oil treatments was observed, and both final fat content and peanut oil main treatments were also significant ($p<0.05$). A graph of the average responses at each treatment combination is shown in Figure 3. The significant interaction is indicated by the lack of parallelism of the lines. In general higher cholesterol was observed in products without

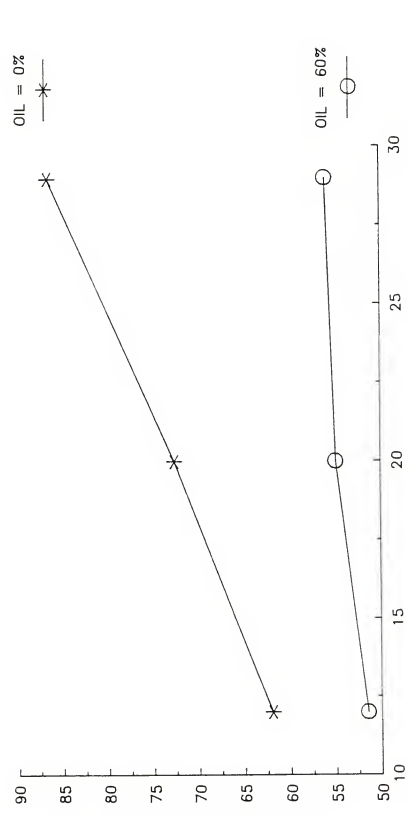
Table 11. Mean values for cholesterol content (mg/100 g) by fat and oil treatments

Oil, [a] %	Final fat, %		
	12	20	29
0	61.98^{z}	72.67^{y}	86.54^{x}
60	51.54^{u}	55.01^{w}	56.06^{w}

[a]Oil treatments were as follow: 0 = No peanut oil; 60 = 60% of the final fat content was peanut oil.

^{u,w,x,y,z}Means in the same row bearing different superscripts differ significantly ($p<0.05$) as indicated by LSD procedure. Means at 60% oil were significantly ($p<0.05$) lower than the means at 0% oil.

Figure 2. Plots of cholesterol vs final fat content at different levels of peanut oil substitution


OIL = 0%
OIL = 60%
CHOLESTEROL, MG/100G
90
85
80
75
70
65
60
55
50
10
15
20
25
30
FINAL FAT CONTENT, %

peanut oil regardless of the final fat content, when compared with products with added peanut oil. In addition, cholesterol content increased in products without peanut oil when the total fat content was increased from 12 to 20 and 29%. However, when oil was added cholesterol content increased when total fat content was increased from 12 to 20% but remained constant with the further increase from 20 to 29%. These finding indicated that the linear increase in cholesterol content due to the increasing total fat was dependent on the level of oil used. The significant cholesterol increase observed when total fat content was increased and no peanut oil was added was expected because of the relatively high cholesterol content in the beef fat (Table 12). On the other hand the significant reduction in cholesterol levels when peanut oil was substituted for beef fat was also expected because it is known that peanut oil does not have cholesterol (Table 12). In products where 60% of the beef fat was removed and substituted with peanut oil, the lean portion may become more important in determining the final cholesterol content since the lean portion decreased when products with high fat content were formulated (Table 1). This may explain why no further increase in cholesterol was observed when the levels of fat were increased from 20 to 29% at 60% oil substitution. Our results agreed with those of Rhee and Smith (1982) who reported a decrease in cholesterol content in patties when beef fat was decreased.

Table 12. Mean values for proximate composition of raw materials

Characteristics,[a] %	Lean	Beef fat	Peanut oil
Protein	22.00	6.00	0.00
Fat	5.30	80.00	100.00
Moisture	70.00	14.00	0.00
Cholesterol	63.24	154.00	0.00
Phytosterol	0.00	0.00	144.83

[a]Characteristics were expressed as g/100 g of tissue, with the exception of cholesterol and phytosterol that were expressed as mg/100 g of tissue.

Sensory and Instrumental Evaluation

Oxidative Rancidity

Oxidative rancidity was evaluated either by sensory rancid flavor detection or by TBA values. A 12-member trained panel was used to detect rancid flavor differences among treatments. Results for rancid flavor evaluation are presented in Table 13. No differences ($p>0.05$) were observed among treatments for rancid flavor evaluation scores either by final fat content or peanut oil content during the six weeks evaluation period. The low score obtained during the six weeks evaluation indicated that even though products with high polyunsaturated fat content were manufactured, no rancid flavor developed during the six weeks storage. These results agreed with the low values obtained with the TBA test (Table 13), and correlate well with the fact that no polyunsaturated fatty acid decrease was detected due to heat or storage conditions. The high polyunsaturated fatty acid content in some products has been considered to be a disadvantage from the point of view of shelf life of the product. The natural proportion and degree of unsaturation of the fatty acid present in a lipid system or food should indicate the approximate susceptibility of that product to oxidative deterioration (Allen and Foegeding, 1981). Keller and Kinsella (1973) demonstrated that changes in the fatty acid composition of lipids provide an indirect measure of susceptibility to lipid oxidation. Generally speaking, the higher the proportion and degree of unsaturation of the fatty acid the more labile the lipid system is to oxidation. Igene and Pearson (1979) reported that both total lipids and total phospholipids significantly increased TBA values and rancid flavor scores; however, triglyceride alone did not significantly

Table 13. Mean values for rancid flavor evaluation and TBA values by final fat content and oil treatments over six weekly intervals of storage time

	Treatments									
	Final fat content, %						Oil, %[a]			
	12		20		29		0		60	
Weeks	RF[b]	TBA[c]	RF	TBA	RF	TBA	RF	TBA	RF	TBA
1	1.08	0.40	1.06	0.41	1.04	0.42	1.07	0.40	1.06	0.41
2	1.07	0.43	1.11	0.39	1.10	0.39	1.10	0.39	1.08	0.41
3	1.12	0.41	1.13	0.41	1.28	0.42	1.14	0.41	1.12	0.41
4	1.16	0.40	1.11	0.40	1.15	0.42	1.12	0.42	1.15	0.41
5	1.18	0.43	1.16	0.43	1.18	0.44	1.17	0.42	1.16	0.44
6	1.26	0.42	1.20	0.42	1.19	0.43	1.21	0.42	1.22	0.43

[a]Oil treatments were as follow: 0 = no peanut oil; 60 = 60% of the final fat content was peanut oil.

[b]RF = rancid flavor was obtained based on a 7-point scale (1 = none; 7 = extremely strong).

[c]TBA = thiobarbituric acid.

influence the development of warmed over flavor in cooked meat. They concluded that the lipids involved in flavor deterioration in cooked meat were the unsaturated fatty acids of the lean tissue which exist primarily as phospholipids. As was previously mentioned, the major polyunsaturated fatty acid was linoleic which is less susceptible to oxidation when compared with polyunsaturated fatty acids with three or more double bonds (Moerck and Ball, 1974).

Factors that affect the rate of rancid flavor development not only include fatty acid composition of the lipid source but also, temperature, light, metal catalysts, inhibitory compounds and availability of oxygen (Labuza, 1971). The fact that the products in the present study were vacuum packaged and antioxidants such as nitrite, phosphate and ascorbate were added may have contributed to the lack of rancid flavor development in the present study. Jantawat and Dowson (1980) reported significantly lower TBA values and less loss in polyunsaturated fatty acids in mechanical deboned turkey when vacuum packaging rather than aerobic packaging was used. Miles et al. (1986) reported that vacuum packaging was effective in reducing TBA values of restructured pork during storage. TBA values were significantly decreased in bologna after 35 days storage when vacuum packaging rather than oxygen permeable film was used (Lin and Sebranek, 1979). The involvement of nitrite, phosphate and ascorbate in the rancid flavor of cooked cured meat has also been of interest. Rancid flavor in turkey frankfurter decreased as nitrite concentration increased (Sales et al., 1980). Low concentrations of nitrate (20 to 50 mg/kg) caused significant inhibition in lipid oxidation as measured by the TBA test in a cooked muscle system (Morrissey and Tichivangana, 1985).

Zipser et al. (1964) proposed that nitrite probably functions as an antioxidant by converting heme proteins to their catalytically inactive and stable nitric oxide heme protein. Tellefson and Bowers (1980) reported that both nitrite and ascorbate inhibited oxidation in turkey emulsion. Sato and Hegarty (1971) concluded that ascorbate retarded autoxidation by reducing Fe^{+++} to Fe^{++} or by oxygen scanvenging. The antioxidant effect of polyphosphates was shown by Miles et al. (1986) who worked with restructured pork. The antioxidant effect of phosphate has been attributed to its ability to chelate metal ions. Beside all of these factors, it is possible that the skin formed during cooking and smoking of frankfurters constitutes a barrier that protects against inclusion of possible oxygen remaining after vacuum packaging. The TBA values found in frankfurters in this study are in general agreement with the ones found in weiners by Siu and Draper (1978). The present TBA values also are in general agreement with those found in a 35 days storage of bologna reported by Lin and Sebranek (1979).

Juiciness

The sensory multiple comparison technique (Larmond, 1970) was used to evaluate differences in juiciness of frankfurters due to final fat content and oil treatments. Results presented in Table 14 showed that final fat content had a significant effect ($p<0.05$) on the juiciness scores of the frankfurters. No differences in juiciness were found in frankfurters with either 20 or 29% final fat content. However, frankfurters with 12% final fat content received lower ($p<0.05$) juiciness scores. This significant decrease in juiciness may be explained by the low fat content along with the significant decrease in cooking yield and significantly less added water observed in products

Table 14. Mean values for sensory characteristics of frankfurters by final fat content and oil treatments evaluated by the multiple comparison test

Characteristics	Treatments				
	Final fat content, %			Oil, %[a]	
	12	20	29	0	60
Juiciness[b]	3.52[x]	4.83[y]	4.97[y]	4.45	4.43
Flavor[c]	5.56[x]	5.09[y]	5.11[y]	5.35	5.15
Color[d]	7.50[x]	6.39[y]	4.96[z]	6.21	6.35
Texture[e]	7.05[x]	5.84[y]	5.01[z]	5.97	5.96

[a]Oil treatments were as follow: 0 = No peanut oil; 60 = 60% of the final fat content was peanut oil.

[b]Means values for juiciness were based on a 9-point scale (9 = extremely juicier than R; 1 = extremely less juicy than R).

[c]Mean values for flavor were based on a 9-point scale (9 = extremely more intense than R; 1 = extremely less intense than R).

[d]Mean values for color were based on a 9-point scale (9 = extremely darker than R; 1 = extremely lighter than R).

[e]Mean values for texture were based on a 9-point scale (9 = extremely firmer than R; 1 = extremely softer than R).

[x,y,z]Means on a row and within a treatment group bearing a different superscript differ significantly ($p<.05$) as indicated by LSD procedure.

R = Frankfurters containing 29% final beef fat.

with 12% final fat content. Even though 12% fat products were found to be significantly less juicy, they were scored as only moderately to slightly less juicy (3.52) than the 20 and 29% final products.

No differences ($p>0.05$) were observed in juiciness due to the oil treatments. It may be expected that because of the lower melting point of the peanut oil, treatments that contain peanut oil would be juicier than those without peanut oil. However, products were served to the panelists after being warmed to an internal temperature sufficient to melt the saturated fat and consequently may have masked any characteristic differences due to the fat softness.

Flavor Intensity

Frankfurters with 12% final fat content were found significantly higher in flavor intensity when compared with those with 20 and 29% final fat content (Table 14). This higher flavor intensity may be explained by the decrease observed in juiciness. The higher shrinkage and less moisture retention during cooking would produce an increase in the salty perception and overall spicy flavor of the products via a concentration of these ingredients. However, the 12% final fat products were scored (5.56) only slightly more intense than those with 20% (5.09) and 29% (5.11) final fat product. No differences ($p>0.05$) in flavor were found due to the increase in peanut oil content.

Color

External color scores as evaluated by a trained panel indicated that darkness increased ($p<0.05$) when the final fat content decreased (Table 14). Products with 12% final fat content were scored as being moderately darker than the 29% fat product reference, while products

with 20% final fat content were found to be slightly darker than the one with 29% fat content. There were no differences ($p>0.05$) observed in external color of frankfurters due to the oil treatments.

Color was also evaluated instrumentally using the Hunter Color and Color Difference Colorimeter. Results for external color evaluations are presented in Table 15. It can be observed that external characteristics were affected by the final fat content but not by the oil treatments. This was in agreement with the results found by the sensory panel for the external color evaluation. External hue angle and lightness decreased as the final fat content decreased from 29 to 20 to 12%, which compares with the increase in darkness observed by the trained panelists. External saturation index increased ($p<0.05$) when fat content was reduced from 29 to 20%, but no further increase ($p>0.05$) was observed when fat content was reduced from 20 to 12%.

Internal color characteristics were affected by both final fat content and oil treatments (Table 15). Internal hue angle and lightness decreased as the final fat content decreased, and increased as the oil content increased. Internal saturation index increased as the final fat content decreased, but was not affected ($p>0.05$) by the oil treatments. The differences in color characteristics found by both sensory and instrumental evaluations could be attributed to an increase in myoglobin content resulting from the increase in the lean portion added when fat content was reduced. The higher shrinkage during cooking in products with low fat content may have also contributed to a darker appearance of those products. The differences in internal color due to oil content may be attributed to the better distribution of the

Table 15. Mean values for instrumental evaluation of color characteristics by final fat content, oil percentage and storage treatments

Characteristics	Treatments[a]						
	Final fat content, %			Oil, %		Storage	
	12	20	29	0	60	F	S
External color							
Hue angle[b]	33.04^{x}	37.42^{y}	43.20^{z}	38.09	37.68	37.71	38.06
Sat. index[c]	21.80^{x}	21.20^{x}	18.20^{y}	20.50	20.30	20.22	20.58
Lightness	37.54^{x}	40.58^{y}	45.40^{z}	40.91	41.44	41.11	41.24
Internal color							
Hue angle	35.48^{x}	39.81^{y}	44.25^{z}	37.00^{x}	42.64^{y}	40.00	39.78
Sat. index	14.93^{x}	14.24^{y}	13.56^{z}	14.23	14.25	14.36	14.13
Lightness	49.43^{x}	51.72^{y}	55.00^{z}	49.35^{x}	54.75^{y}	52.06	41.24

[a] Treatments were as follow: 0= No peanut oil; 60= 60% of the final fat content was added peanut oil; F= Fresh, color determination was made 48 hr after being manufactured; S= Storage, color determination was made after six weeks of storage at 4°C.

[b] Hue angle = $\tan^{-1}$ b/a = "color name".

[c] Saturation index = $(a^2 + b^2)^{1/2}$ = "intensity of the color".

^{x,y,z} Means on a row and within a treatment group bearing different superscripts differ significantly ($p<0.05$) as indicated by LSD procedure.

oil during emulsification. The lack of differences in the external color characteristics due to the oil treatments may be explained by the severe heat treatment that products underwent on the surface during smokehouse cooking which tend to darken the surface and mask any possible differences.

Mean values of the instrumental color characteristics as affected by storage condition are shown in Table 15. It appears from these data that six weeks storage had no effect ($p>0.05$) on internal and external color characteristics. These results may be explained by the use of vacuumized storage conditions and the surface exposure of the frankfurters' skin to the light. Fading of the cured color due to the storage conditions has been reported by several researchers (Lin and Sebranek, 1979; Gountenfogea, 1980). Lin and Sebranek (1979) reported that the color of vacuum packaged, sliced bologna faded with storage time but was still acceptable after 35 days of storage. A major difference observed between their study and the present study was that the cured surface of sliced bologna was exposed directly to the light and to oxygen diffusing through the packaging film which will produce dissociation of the nitroso-hemochrome pigment responsible for the pink cured color. However, in the present study where smokehouse cooking was used, frankfurters developed a semi-dry skin with a stable color that protected the rest of the product from color fading.

Because of the importance of color acceptability at the retail level, a study was conducted to determine the color acceptability of the different treatments. A hedonic scale, as shown in Table 3, was used and 120 consumer panelists were asked to evaluate the product.

No differences ($p>0.05$) were observed in color acceptability either by final fat content or by peanut oil treatments (Table 16). Results indicated that even though significant differences in color were detected by the trained panel using the multiple comparison technique, these differences did not influence consumer acceptability. The lack of differences in consumer acceptability of frankfurters may be related to the wide range of colors for frankfurters presently observed in the market place.

Firmness

Mean values for sensory evaluation of firmness (expressed as texture) by final fat content and oil treatments are shown in Table 14. Results indicated that panelist did find differences ($p<0.05$) in the firmness of frankfurters due to the final fat content. Firmness of the frankfurters increased as the final fat content decreased. Products with 12% final fat content were evaluated to be moderately firmer (7.05) than the ones with 29% final fat content (5.01), while products with 20% final fat content were evaluated to be slightly firmer (5.84) than the ones with 29% final fat content. No major changes were observed in the firmness of frankfurters due to the oil treatments ($p>0.05$).

Instrumental evaluation of texture was performed using the Universal Instron Machine. Mean values for shear stress and texture profile characteristics expressed as fracturability, hardness, cohesiveness, springiness, gumminess and chewiness are presented in Table 17. Shear stress and texture profile characteristics increased ($p<0.05$) as the final fat content decreased but were not affected by

Table 16. Mean values for consumer evaluations by final fat content and oil treatments

Characteristics[b]	Treatments				
	Final fat content, %			Oil, %[a]	
	12	20	29	0	60
Overall acceptability	6.14[x]	6.99[y]	7.18[y]	6.75	6.80
Color acceptability	6.40	6.96	6.82	6.65	6.80

[a]Oil treatments were as follow: 0 = No peanut oil; 60 = 60% of the final fat content was peanut oil.

[b]Means for overall acceptability and color acceptability were obtained based on a 9-point scale (9 = extremely like; 1 = extremely dislike).

[x,y]Means on a row and within a treatment group bearing different superscripts differ significantly ($p<0.05$) as indicated by LSD procedure.

Table 17. Mean values for instrumental evaluation of textural characteristics by final fat content, oil and storage treatments

Characteristics	Treatments						
	Final fat content, %			Oil, %[a]		Storage[b]	
	12	20	29	0	60	F	S
Shear stress, g/cm^2	103.42^x	94.49^y	82.10^z	93.80	93.67	93.13	93.54
Fracturability, kg	14.19^x	10.14^y	6.40^z	10.30	10.11	10.25	10.23
Hardness, kg	14.30^x	10.29^y	6.09^z	10.21	10.25	10.19	10.27
Cohesiveness[c]	0.38^x	0.30^y	0.25^z	0.31	0.31	0.31	0.30
Springiness, mm	2.97^x	1.97^y	1.31^z	2.00	2.40	2.09	2.63
Gumminess[d], kg	5.45^x	3.07^y	1.55^z	3.59	3.35	3.03	3.38
Chewiness[e], kg.mm	16.63^x	6.04^y	2.01^z	8.24	8.21	8.38	8.07

[a]Oil treatments were as follow: 0 = No peanut oil; 60 = 60% of the final fat content was peanut oil.

[b]Storage treatments were as follow: F = fresh, determination was made four days after being prepared; S =Storage, determination was made after six weeks of storage at 4 C.

[c]Cohesiveness = A1/A2.

[d]Gumminess = Hardness x Cohesiveness.

[e]Chewiness = Gumminess x Springiness.

^{x,y,z}Means on a row and within a treatment group bearing different superscripts differ significantly ($p<0.05$) as indicated by LSD procedure.

the oil addition.

Reducing the fat content in frankfurters has been reported to increase firmness (Sofos and Allen, 1977; Foegeding and Ramsey, 1986), gumminess and chewiness (John et al., 1986). The increase in textural firmness characteristics when fat content is decreased should be expected due to the important role that fat plays in giving tenderness to food. The increase in shear stress, fracturability and hardness may be explained by both the substantial decrease in fat and the increase in protein content. Sofos and Allen (1977) reported an increase in firmness of frankfurters when textural soy protein was substituted for fat in the manufacture of a low fat frankfurter product. Huffman and Powell (1970) reported that significantly less force was required to shear patties containing approximately 35% fat than those containing approximately 29 or 15% fat. Cohesiveness and springiness are mechanical properties highly dependent on the strength of the internal molecule bonds making up the body of the product (De Man, 1980). Thus, it could be expected that cohesiveness and springiness were affected mainly by the protein-protein interaction in meat products. Since the protein-protein interaction increased as protein content increased, cohesiveness and springiness would be expected to be higher in products with lower fat and higher protein content. The observed increase in hardness, cohesiveness and springiness as the fat content decreased and the protein content increased may explain the increase in gumminess which is the product of hardness and cohesiveness. These changes may also explain the increase in chewiness which is the product of springiness and gumminess.

Overall Acceptability

A nine point headonic scale was used to evaluate overall acceptability of the different frankfurter treatments. Results of the overall acceptability evaluations are shown in Table 16. There were significant differences ($p<0.05$) in the overall acceptability of the frankfurters due to the final fat content treatments, but not due to the peanut oil treatments ($p>0.05$). Products with 12% final fat content received lower scores (6.14) than products with either 20 (6.99) or 29% (7.18) final fat content. Results also indicated that even though differences were observed among product groups, all products were evaluated as acceptable (scores >5) by the panelists. The results of this study are in agreement with those reported by Sofos and Allen (1977) and Foegeding and Ramsey (1986) in that frankfurters with low fat content were acceptable to the consumer panelists. However, this results disagree with Foegeding and Ramsey (1986) who reported no differences in overall acceptability between low fat (12%) and high fat (26.9%) products. The reason for this discrepancy may be that their high fat products were also high in protein (16%) which is an important factor in increasing firmness of the product and may mask any detectable difference due to the fat content. Since products were served with ketchup and mustard that tend to mask flavor, color and juiciness, it may be possible that the differences detected in overall acceptability are better explained by differences in texture which can not be masked by sauce. The lack of differences in overall acceptability between the 20 and 29% final fat products agreed with the results of John et al. (1986) who reported no differences in overall acceptability when 22.5% and 29% final fat products were compared.

Rabbit Study

Because of the increasing concern by the consumer about the nutritional quality of food, a study of the hyperlipidemic effect of treatments with 12 and 29% final fat content, with and without peanut oil, was conducted using rabbits as experimental units. Rabbits have been used as a model system because their mechanism of cholesterol synthesis and control resemble that of humans. In both cases the extrahepatic cholesterol synthesis is important and the control of cholesterol synthesis is mainly in the liver (Harper et al., 1979). In addition low density lipoproteins (LDL) is the major cholesterol transport system in the rabbit as in the humans. However, since rabbits are not accustomed to eating cholesterol or diets high in fat and since their plasma cholesterol levels (45 mg/100 ml) are relatively low compared to humans (200 mg/100 ml), they are very sensitive and respond very rapidly when fed diets containing cholesterol and saturated fatty acids.

Mean values of weight gain and daily intake of treated rabbits during the six weeks of experiments are presented in Table 18. No differences in weight gain were observed among treatments. Rabbits fed with treatments containing 29% final fat without peanut oil had a significant lower daily intake when compared to the other treatments.

Mean values for serum cholesterol and triglyceride levels in rabbits by dietary treatments and by week are presented in Table 19 and 20. Values reported for week 2 represent the base line or initial values for cholesterol or triglyceride levels in rabbit serum. Values reported at week 3 correspond to the levels of cholesterol or

Table 18. Mean values for initial and final weights, weight gain, and daily intake of treated rabbits

Treatments[a]	Initial weight, kg	Final weight, kg	Weight gain, kg	Daily intake, kg
12-0 (6)[b]	2.62	2.98	0.36	0.16[x]
12-60 (5)	2.50	2.86	0.36	0.15[x]
29-0 (6)	2.32	2.65	0.33	0.12[y]
29-60 (6)	2.36	2.70	0.34	0.16[x]
Control (5)	2.37	2.72	0.35	0.17[x]

[a]Treatments were as follows: ; 12-0 = commercial chow + franks with 12% final fat content; 12-60 = commercial chow + franks with 12% final fat content, 60% of which was peanut oil; 29-0 = commercial chow + franks with 29% final fat; 29-60 = commercial chow + franks with 29% final fat, 60% of which was peanut oil; Control = commercial chow only.

[b]Number of animals in each treatment.

[x,y]Means on a column bearing different superscripts differ significantly ($p<0.05$) as indicated by Duncan's Multiple Range procedure.

Table 19. Mean values for serum cholesterol (mg/100 ml) of rabbits by dietary treatments over six weekly intervals

Weeks[b]	Treatments[a]				
	12-0	12-60	29-0	29-60	Control
2	45.01^{x}	44.29^{x}	47.13^{x}	43.69^{x}	44.53^{x}
3	53.03^{x}	46.12^{x}	56.43^{x}	53.17^{x}	48.89^{x}
4	53.73^{y}	49.59^{y}	64.43^{x}	54.08^{y}	46.91^{y}
5	63.92^{xy}	49.36^{z}	72.28^{x}	59.08^{yz}	47.93^{z}
6	70.45^{xy}	54.90^{z}	78.73^{x}	63.61^{yz}	47.50^{z}

[a]Treatments were as follow: 12-0 = rabbits were fed with commercial chow + franks with 12% final fat content; 12-60 = rabbits were fed with commercial chow + franks with 12% final fat content, 60% of which being peanut oil; 29-0 = rabbits were fed with chow + franks with 29% final fat; 29-60 = rabbits were feed with chow + franks with 29% final fat, 60% of which being peanut oil; Control = rabbits were fed only with commercial chow

[b]Weeks were as follows: 2 = rabbits were fed with commercial chow during the first and second weeks; 3 = rabbits were fed with commercial chow plus 5 g of their respective treatment; 4 = rabbits were fed with commercial chow plus 7.5 g of their respective treatments; 5 and 6 = rabbits were fed with commercial chow and 10 g of their respective treatments.

^{x,y,z}Means on a row bearing different superscripts differ significantly ($p<0.05$) as indicated by Duncan's Multiple Range procedure.

Table 20. Mean values for serum triglyceride (mg/100 ml) of rabbits by dietary treatments over six weekly intervals

Weeks[b]	Treatments[a]				
	12-0	12-60	29-0	29-60	Control
2	35.58^{x}	35.38^{x}	36.69^{x}	40.53^{x}	36.82^{x}
3	40.58^{y}	39.12^{y}	40.08^{y}	51.24^{x}	36.33^{y}
4	48.70^{y}	47.51^{y}	53.45^{xy}	60.16^{x}	39.14^{z}
5	57.11^{y}	56.25^{y}	73.56^{x}	76.80^{x}	38.75^{z}
6	67.21^{y}	65.59^{y}	89.40^{x}	88.71^{x}	39.94^{z}

[a]Treatments were as follow: 12 = rabbits were fed with commercial chow + franks with 12% final fat content; 12-60 = rabbits were fed with commercial chow + franks with 12% final fat content, 60% of which being peanut oil; 29 = rabbits were fed with chow + franks with 29% final fat; 29-60 = rabbits were feed with chow + franks with 29% final fat, 60% of which being peanut oil; Control = rabbits were fed only with commercial chow.

[b]Weeks were as follows: 2 = rabbits were fed with commercial chow during the first and second weeks; 3 = rabbits were fed with commercial chow plus 5 g of their respective treatment; 4 = rabbits were fed with commercial chow plus 7.5 g of their respective treatments; 5 and 6 = rabbits were fed with commercial chow and 10 g of their respective treatments.

^{x,y,z}Means on a row bearing different superscripts differ significantly ($p<0.05$) as indicated by Duncan's Multiple Range procedure.

triglyceride when rabbits were fed with 5 g of their respective treatments. Values reported at week 4 correspond to the levels of cholesterol or triglyceride when rabbits were fed with 7.5 g of their respective treatments. Values reported at weeks 5 and 6 correspond to the levels of cholesterol when rabbits were fed with 10 g of their respective treatments. Commercial rabbit chow and water were provided ad libitum. The results indicated that nearly all of the treatment combinations yielded a significant increase in the serum cholesterol and triglyceride levels of rabbits when compared to the control after the six weeks of feeding. The single exception with serum cholesterol was the treatment 12-60 (12% final fat content with 60% as peanut oil). Diets without peanut oil produced the highest levels of serum cholesterol. Serum triglyceride was highest with the 29% final fat dietary treatments regardless of the presence of peanut oil.

Plots of the linear regression equations of the serum cholesterol values over the six week dietary period are shown in Figure 4. Tests performed on the slopes of the fitted equations indicated that rabbits without dietary peanut oil had a significantly higher rate of increase (steeper slope of the regression equation) in the serum cholesterol than rabbits receiving the dietary peanut oil treatment (Table 21). In the diets containing peanut oil, even though increases in the rate of serum cholesterol levels were observed (slopes were 2.34 and 4.57 mg/100 ml/week), the rates of increase were not significantly greater than with the control.

Because of the heterogeneous composition of the products, it is rather difficult to explain the differences in the serum cholesterol of rabbits using the addition of peanut oil as the only factor.

Figure 3. Plots of simple regression equations of average serum cholesterol levels vs time by dietary treatments

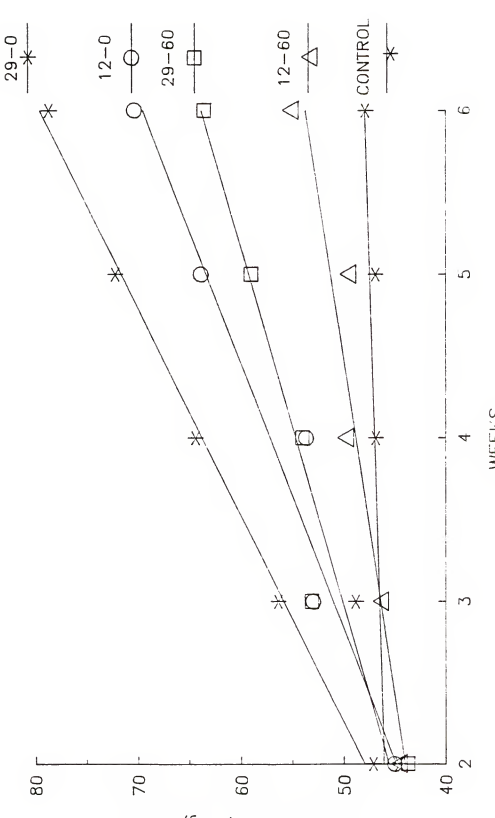

29-0
12-0
29-60
12-60
CONTROL
CHOLESTEROL, mg/100ml
80
70
60
50
40
2
3
4
5
6
WEEKS

Table 21. Estimates of regression slopes for cholesterol and serum triglyceride levels by different treatments

Treatments[a]	Regression slopes	
	Cholesterol	Triglyceride
12-0	6.18^{y}	7.98^{y}
12-60	2.34^{x}	7.96^{y}
29-0	7.90^{y}	13.89^{z}
29-60	4.57^{x}	12.19^{z}
CONTROL	0.55^{x}	0.95^{x}

[a]Treatments were as follow: 12-0 = rabbits were fed with commercial chow + franks with 12% final fat content; 12-60 = rabbits were fed with commercial chow + franks with 12% final fat content, 60% of which being peanut oil; 29-0 = rabbits were fed with chow + franks with 29% final fat; 29-60 = rabbits were feed with chow + franks with 29% final fat, 60% of which being peanut oil; CONTROL = rabbits were fed only with commercial chow.

^{x,y,z}Slope estimates in the same column having different superscripts differ at the $p<0.05$ level.

Combinations of factors such as the higher concentration of polyunsaturated fatty acids and a concomitant lower concentration of saturated fatty acids in the final peanut oil product (Table 9), plus the lower cholesterol content in the peanut oil products (Table 11) may be responsible for the differences in serum cholesterol. Several studies have demonstrated that polyunsaturated fatty acids derived from vegetable oil will reduce plasma cholesterol levels in rabbits (Ahrens et al., 1957; Funch, et al., 1962; Kritchevsky et al., 1971; Shepherd et al., 1980). However, Kritchevsky et al. (1971, 1976) reported that peanut oil was unexpectedly atherogenic for rabbits and velvet monkeys when fed as part of a 2% cholesterol-containing diet. They also reported that peanut oil was more atherogenic than corn oil when fed to rabbits as part of a semipurified hyperlipidemic and hyperlipoproteinemic cholesterol-free diet. They attributed the atherogenecity of peanut oil to the presence of long chain fatty acids such as arachidic (20:0) and behenic (22:0). In addition, since autorandomized peanut oil lowered the atherogenic potency of normal peanut oil, they concluded that the structure of triglycerides was also important. Tsoa et al. (1984) investigated whether the absorption of dietary cholesterol in rats was altered in the presence of peanut oil or randomized peanut oil. They reported no difference in cholesterol absorption and concluded that the differences in atherogenicity between the peanut oil and the randomized peanut oil were probably caused by events subsequent to the absorption of cholesterol. In our study, even though we confirmed the presence of long chain fatty acids in peanut oil, they were in low amounts (Table 10). The fact that Kritchevsky

and coworkers (1971, 1976) used hyperlipidemic dietary treatments in all of the experiments mentioned may explain the high plasma cholesterol levels observed in their experiments. In addition, since in our study we compared a saturated animal fat against peanut oil, this may explain the differences in the results obtained between the present study and those by Kritchevsky and coworkers (1971, 1976) who compared peanut oil against corn oil which is a more polyunsaturated fat than peanut oil.

The increase in the ratio of polyunsaturated to saturated (P/S) fatty acids from 0.11 in products without peanut oil to 0.68 in products with peanut oil (Table 9) may help to explain the differences noted in our experiments in serum cholesterol response. Not only the presence of polyunsaturated fatty acids but also the ratio of polyunsaturated to saturated (P/S) fatty acids has been indicated as an important dietary factor in determining plasma cholesterol by some investigators. Ahrens et al. (1957) suggested that a certain percentage of polyunsaturated fat is required in the human diet before serum cholesterol is lowered. Shepherd et al. (1980) working with humans reported a decrease in plasma cholesterol of 23% when using a P/S ratio equal to 4. However, Hill and Wynder (1976) reported no differences in serum cholesterol levels when the P/S ratio was increased from 0.3 to 1.2. Thus, the relationship of P/S ratio to serum cholesterol levels remains controversial.

Since cholesterol-rich diets have regularly caused hypercholesterolemia in experimental rabbits (Camejo et al., 1973; Shireman et al., 1983), the differences in cholesterol content in

dietary products in the present study may explain the higher serum cholesterol content found in rabbits fed with higher cholesterol products even though the daily cholesterol intake in all cases was very low (Table 22). Overall, the increases in the serum cholesterol during the six weeks of dietary treatments were much lower than those reported in the literature by others investigators. However, in most studies much higher cholesterol levels (1 to 2 g/100 g) were used as compared to the levels of dietary cholesterol in our study. Our observations suggest that besides the higher saturated fatty acid content in products without peanut oil, other factors may be involved in the increase of serum cholesterol since there were no differences due to the final fat content of dietary treatments. As previously mentioned, products from different treatment groups were highly variable in composition, i.e., those products with higher fat content had the lower protein content while products with lower fat had the higher protein content. As a further complication, it has been reported that animal protein tends to increase serum cholesterol in rabbits. Carrol and Hamilton (1975) reported that rabbits consuming animal proteins, including casein and beef, had higher plasma cholesterol levels than those on diets containing only plant proteins. They also reported that the addition of corn oil to the diet largely prevented the rise in plasma cholesterol. Consequently, it may be possible that the lack of differences observed in this study due to the final fat content resulted from the higher protein content in products with low fat content. On the other hand, it may be that the 12% animal fat content in frankfurters is sufficiently high to produce a response similar to

Table 22. Average daily intake of cholesterol (mg) and total fat (g) given by frankfurter treatments

Weeks	Treatments[a] 12-0 C[b]	12-0 F[c]	12-60 C	12-60 F	29-0 C	29-0 F	29-60 C	29-60 F	Control C	Control F
1	---	---	---	---	---	---	---	---	---	---
2	---	---	---	---	---	---	---	---	---	---
3	3.10	0.61	2.58	0.61	4.33	1.45	2.80	1.45	---	---
4	4.65	0.92	3.87	0.92	6.49	2.18	4.20	2.18	---	---
5	6.20	1.22	5.15	1.22	8.65	2.89	5.61	2.89	---	---
6	6.20	1.22	5.15	1.22	8.65	2.89	5.61	2.89	---	---

[a]Treatments were as follows: 12-0 = commercial chow + franks with 12% final fat content; 12-60 = commercial chow + franks with 12% final fat content, 60% of which was peanut oil; 29-0 = commercial chow + franks with 29% final fat; 29-60 = commercial chow + franks with 29% final fat, 60% of which was peanut oil; Control = commercial chow only.

[b]C = cholesterol

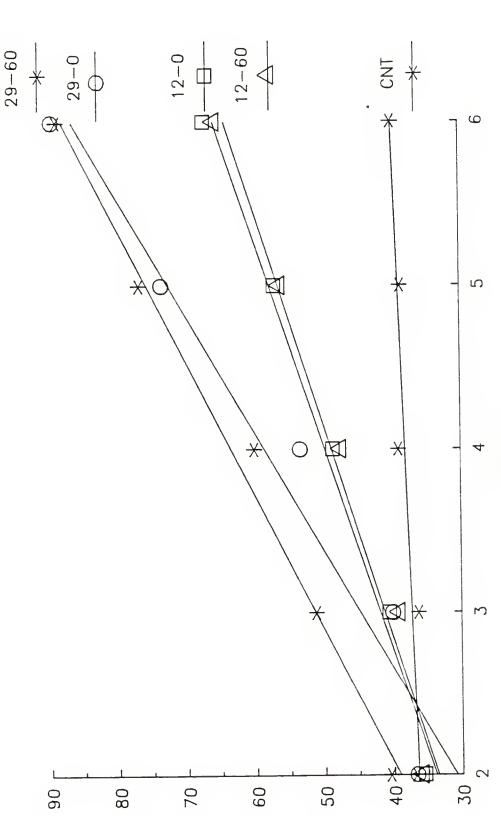
[c]F = fat

the one obtained with 29% animal fat.

Plots of linear regression equations of serum triglyceride responses during the six weeks dietary treatments are shown in Figure 5. Tests performed on the slopes of the fitted equations suggested that the inclusion of frankfurters in rabbits' diets caused a significantly higher rate of increase in the serum triglyceride than in the control during the six weeks of the experiment (Table 21). Results also suggested that the final fat content had a significant effect on the serum triglyceride content of rabbits. Products with 29% final fat content induced a greater increase in serum triglyceride levels when compared to products with 12% final fat content. These results are in agreement with Shireman et al. (1983) who reported an increase in triglyceride levels of rabbits in a four week dietary period when the total fat content of the commercial chow was increased by the addition of 3% coconut oil. No differences in serum triglyceride increase were observed due to the peanut oil addition.

Investigators who have studied the effects of polyunsaturated fatty acids upon plasma triglyceride levels have occasionally reached divergent conclusions. Connor et al. (1981) reported that when polyunsaturated fatty acids from vegetable oil were incorporated in the diet, no effect of vegetable oil upon triglyceride levels was observed when a dietary period of four weeks was used. Chait et al. (1974) reported a decrease in triglyceride levels when polyunsaturated fatty acids were used in the diet; however, their study involved a dietary period of only 10 days duration and it may be possible that the study may have been too short to allow for stabilization of plasma lipid

Figure 4. Plots of simple regression equations of average serum triglyceride levels vs time by dietary treatments.


29-60
29-0
12-0
12-60
CNT
TRIGLYCERIDE, mg/100ml
WEEKS
90
80
70
60
50
40
30
2
3
4
5
6

content. Shepherd et al. (1980) reported that plasma triglyceride levels were depressed by only 13% during vegetable oil feeding. These findings seem to indicate that the feeding of polyunsaturated fatty acids has a minimal effect upon the plasma triglyceride levels. However, those experiments were conducted in humans and vegetable oils other than peanut oil were used.

Overall, results of this study indicate that the inclusion of peanut oil in the diet produces a smaller serum cholesterol response when compared with the dietary treatments without peanut oil, but this substitution apparently does not have any effect on triglyceride levels. Nevertheless, since the inclusion of peanut oil in the diet resulted in an increase in polyunsaturated fatty acids, a decrease in cholesterol content and a decrease in saturated fatty acids, it is difficult to establish which of these factors was the main determinant of the response. In fact the results obtained may have been a consequence of all the factors combined.

There was no apparent relationship between the daily intake and the rate of hypercholesterolemia produced by the diets. Rabbits fed frankfurters containing 29% beef fat had significantly ($p<0.05$) lower daily intake (Table 18), but did not differ ($p>0.05$) in the rate of serum cholesterol increase.

During these experiments two rabbits became sick; one suffered dehydration and died, and the other contracted an ear infection. In both cases, serum cholesterol levels (470 mg/100 ml and 144 mg/100 ml, respectively) and serum triglyceride levels (138 mg/100 ml and 100 mg/100 ml respectively) were extremely higher at week four compared

with the serum cholesterol and triglyceride levels of the other rabbits. Therefore, these values were not used in final calculations.

Because rabbits are very sensitive and respond very rapidly when fed with high fat dietary treatments, the fast response in cholesterol and triglyceride levels observed in this study cannot be directly extrapolated to expected responses in human. However, as it was mentioned the mechanisms of synthesis, control and transport of cholesterol in rabbits resemble the mechanisms in humans. Consequently, the differences observed in cholesterol responses due to the addition of peanut oil and triglyceride responses due to the levels of fat in this study may give insight into what could happen in humans if exposed for certain periods of time to these types of diets.

SUMMARY AND CONCLUSION

The effect of reducing the final fat content and the addition of peanut oil on the stability, fatty acid profile, cholesterol content, shelflife, quality properties and overall acceptability of frankfurters were evaluated.

Six different treatments (11.36 kg batches in triplicate) with different final fat content (12, 20 and 29%), and with and without peanut oil substituted for beef fat (0%, 60%), were prepared. Final products were evaluated fresh and after six weeks of storage at $4^{o}C$. The effect of cooking and storage condition on the fatty acid profile were also evaluated. Finally, the potential hyperlipidemic effect of products with 12% and 29% final fat content with and without peanut oil was evaluated using rabbits as experimental units.

Emulsion stability, expressed as milliliters of water loss during heating per 34 g emulsion was reduced ($p<0.05$) when the final fat content was reduced to 12%, but was not affected by the addition of peanut oil. This correlates well with the lower yield, lower added water and lower juiciness scores observed for products with 12% final fat.

Fatty acid profile of the final products was affected by peanut oil treatments but was not changed by fat level treatments. The polyunsaturated to saturated fatty acid ratio increased from 0.11 to 0.68 when peanut oil was added. No differences were observed in fatty acid profile because of cooking or storage condition.

Cholesterol content decreased when both final fat content decreased and oil content increased; however, an interaction was observed among the two factors with regard to cholesterol content, indicating that the linear increase in cholesterol content because of the increasing total fat was dependent on the level of oil used.

Firmness and external color, as evaluated by a trained panel, increased as the final fat content decreased but were not affected by the addition of peanut oil. Shear stress and overall texture profile increased linearly as the final fat content decreased but were not affected by the addition of peanut oil. Hunter external color characteristics as measured by hue angle, saturation index and lightness were affected by the different levels of final fat content, but not by addition of peanut oil. Hue angle and lightness decreased, while the saturation index increased when the final fat content was decreased. No differences in overall color acceptability as evaluated by a consumer panel were observed.

No rancid flavor development was detected during the six weeks storage at $4^{o}C$, as determined by sensory evaluation and TBA values. Flavor, color, and texture were stable during the six weeks of storage. All the treatment combinations were evaluated as acceptable by the consumer panel; however, treatments with 12% final fat either with or without peanut oil received significantly lower scores than the other treatment groups.

All treatment combinations significantly increased the serum triglyceride levels of rabbits when compared to the control after six weeks of feeding. Those with higher fat contents produced a greater increase. Treatments without peanut oil significantly increased the

rabbits' serum cholesterol level. Treatments with peanut oil and 29% final fat content showed an increase in the rabbits' serum cholesterol level when compared to the control after six weeks feeding.

In conclusion, these results indicate that products with 12% fat content were scored as acceptable, even though they received lower scores when compared with higher fat content products (20 or 29%). Addition of peanut oil did not change the overall acceptability of the products. Cholesterol can be reduced by either reducing the final fat content or by adding peanut oil as a substitute for beef fat. The ratio of polyunsaturated to saturated fatty acids can be increased by the addition of peanut oil, but does not change by reducing final fat content. Because of the lower yield and lower added water observed in products with 12% final fat content, more research needs to be done in this area to fully understand the behavior of the myofibrillar protein when low fat meat emulsions are formulated.

Results also indicate that the 60% substitution of peanut oil for beef fat in the diets of rabbits produced a lower serum cholesterol response, as compared with the dietary treatments without peanut oil. However, this substitution apparently does not have any effect on triglyceride levels. Serum triglyceride levels were increased by increasing the amount of fat in the diet regardless of the presence of peanut oil. Since the inclusion of peanut oil in the diet resulted in an increase in polyunsaturated fatty acids, a decrease in saturated fatty acids, and a decrease in cholesterol content, it is difficult to sort out which one was the main determinant of the response. Consequently, the results obtained may have been a consequence of all the factors combined.

APPENDIX

Table 23. Analysis of variance for some characteristics of the products

Source	df[a]	Water Released		Yield		Cholesterol	
		MS[b]	Ft/e[c]	MS[d]	Ft/e	MS	Fe/t
F	2	4.60	13.15	11.15	5.44	317.43	75.40
O	1	0.24	<1	0.15	<1	1655.19	393.16
F*O	2	0.09	<1	0.27	<1	158.15	37.56
Error	12	0.35	--	2.05	--	4.21	--

[a]df = degrees of freedom.

[b]MS = mean square.

[c]Ft/e = mean square treatment/mean square error.

[d]F = fat.

[e]O = oil.

[f]F*O = fat and oil interaction.

Table 23. Continued

Source	df	Palmitic acid		Linoleic acid		Color lightness		Shear stress	
		MS	Ft/e	MS	Ft/e	MS	Ft/e	MS	Ft/e
F	2	0.77	<1	0.78	<1	188.22	133.49	1310.06	151.98
O	1	558.72	498.86	1950.55	1972.24	2.55	1.81	3.88	<1
F*O	2	0.27	<1	0.31	<1	0.18	<1	5.17	<1
S[a]	1	0.00	<1	0.74	<1	0.16	<1	1.38	<1
F*S	2	0.56	<1	0.28	<1	0.51	<1	1.38	<1
O*S	1	0.39	<1	0.04	<1	1.35	<1	3.28	<1
F*O*S	2	0.06	<1	0.51	<1	0.21	<1	6.20	<1
Error	24	1.12	--	0.99	--	1.41	--	8.62	--

[a]S = storage.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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